SATURN S-IVB-208 STAGE
ACCEPTANCE FIRING REPORT

DOUGLAS REPORT SM-47474
27 MARCH 1967

PREPARED BY:
DOUGLAS AIRCRAFT COMPANY, INC.
SATURN S-IVB TEST PLANNING
AND EVALUATION COMMITTEE

PREPARED FOR:
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
UNDER NASA CONTRACT NAS7-101

APPROVED BY: A. P. O'NEAL
DIRECTOR, SATURN DEVELOPMENT ENGINEERING

DOUGLAS MISSILE & SPACE SYSTEMS DIVISION
SPACE SYSTEMS CENTER — HUNTINGTON BEACH, CALIFORNIA

ABSTRACT

This report presents an evaluation of the Saturn S-IVB-208 stage acceptance firing that was conducted at the Sacramento Test Center on 12 January 1967. Included in this report are stage and ground support equipment deviations associated with the acceptance firing configuration.

The acceptance firing test program was conducted under National Aeronautics and Space Administration Contract NAS7-101, and established the acceptance criteria for buyoff of the stage.

DESCRIPTORS

Saturn S-IVB-208 Stage

Saturn S-IVB/V Stage

Saturn S-IVB-208 Stage Test Evaluation

J-2 Engine

Complex Beta

Countdown Operations

Saturn S-IVB-208 Acceptance Firing

Saturn S-IVB-208 Stage Test Configuration

Sacramento Test Center

Sequence of Events

27 March 1967

PREFACE

The purpose of this report is to document the evaluation of the Saturn S-IVB-208 stage acceptance firing as performed by Douglas personnel at the Sacramento Test Center.

This report, prepared under National Aeronautics and Space Administration Contract NAS7-101, is issued in accordance with line item 129 of the MSFC *Data Requirements List 021*, dated 15 September 1966.

This report evaluates stage test objectives, instrumentations, and configuration deviations of the stage, test facility, and ground support equipment.

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1. INTRODUCTION

1.1 General

This report was prepared at the Douglas Huntington Beach Space Systems Center by the Saturn S-IVB Test Planning and Evaluation (TP&E) Committee for the National Aeronautics and Space Administration under Contract NAS7-101.

Activities connected with the Saturn S-IVB-208 stage included a prefiring checkout and the acceptance firing. Checkout started at the subsystem level and progressed to completion with the integrated systems test and the simulated acceptance firing. The information contained in the following sections documents and evaluates all events and test results of the acceptance firing which was completed on 12 January 1967. The tests were performed at the Complex Beta, test stand I, Sacramento Test Center (STC).

1.2 Background

The S-IVB-208 stage was assembled at the Huntington Beach Space Systems Center. A checkout was performed in the vertical checkout laboratory (VCL) prior to shipping the stage to STC. The stage was delivered to STC on 1 December 1966 and installed on test stand I on 2 December 1966. The stage was ready for acceptance firing on 10 January 1967.

The APS modules were shipped to the manufacturing and assembly (M&A) building at STC for leak and functional checks. No confidence firings of these modules were scheduled.

Table 1-1 lists the milestones of the Saturn S-IVB-208 stage events and dates of completion.

1.3 Objectives

All test objectives outlined in Douglas Report No. SM-47458A, *Saturn S-IVB-208 Stage Acceptance Firing Test Plan*, dated November 1966 and revised 20 December 1966 were successfully completed.

Stage acceptance objectives which provided maximum system performance evaluation were as follows:

a. Countdown control and operation capability verification

b. J-2 engine system performance verification

c. Oxidizer system performance verification

d. Fuel system performance verification

e. Pneumatic control system performance verification

f. Propellant utilization system performance verification

g. Stage data acquisition system performance verification

h. Stage electrical control and power system performance verification

i. Hydraulic system performance and J-2 engine gimbal control performance verification

j. Structural integrity verification

k. APS stage interface compatibility verification.

TABLE 1-1
MILESTONES, SATURN S-IVB-208 STAGE

EVENT	COMPLETION DATE
Tank Assembly	18 March 1966
Proof Test	4 April 1966
Insulation and Bonding	25 May 1966
Stage Checkout and Join J-2 Engine	26 August 1966
Systems Checkout	11 October 1966
Ship to STC	1 December 1966
Stage Installed on Test Stand	5 December 1966
Ready for Acceptance Firing	10 January 1967
Acceptance Firing	12 January 1967
Stage Received at VCL	27 January 1967
All Systems Test (Buy-off)	17 March 1967*
Ready for Shipping (Signed DD250)	21 March 1967*

* Projected dates

2. SUMMARY

The S-IVB-208 stage was acceptance fired on 12 January 1967 at Complex Beta, test stand I, Sacramento Test Center. The countdown was designated as CD 614076. The mainstage firing duration was 426.6 sec; engine cutoff was initiated through the propellant utilization (PU) processor when liquid oxygen (LOX) was depleted below the 1 percent level.

2.1 Countdown Operations

CD 614076 was initiated on 11 January 1967 and proceeded smoothly to a successful acceptance firing on 12 January 1967.

The following anomalies were experienced during the countdown:

a. GN2 leakage through the bootstrap piston vent valve path in the accumulator-reservoir was observed at a rate of 5 to 50 psia/hr or up to 2,650 times the allowable minimum. This leakage required replacing the part.

b. During the loading, the LH2 depletion sensor No. 1 cycled intermittently from start of loading for 26 min. Normal operation was observed after this time.

c. There was an engine performance shift shortly after PU valve cutback. This shift was noted in all major engine instrumentation and was reflected in the evaluation computer programs. The PU valve position did not indicate a shift, although a simultaneous increase in oxidizer pump discharge pressure and a decrease in PU valve discharge pressure indicated a change in PU valve effective area. This discrepancy is probably the result of slack in the mechanical linkage connecting the PU valve and the PU valve position transducer.

d. The talkback microswitches of the LOX and LH2 chilldown shutoff valves failed to indicate when the valves were open. This failure was caused by a leak in the seal of the microswitch cover gasket.

e. One measurement failed during the acceptance firing, C0001 (Temperature-LH2 Turbine Inlet, Gas Generator Gas).

2.2 J-2 Engine System

The performance of the J-2 engine (S/N 2062) was satisfactory throughout the acceptance firing. The PU valve did cause a small perturbation as explained in the above paragraph 2.1, but it did not degrade the overall performance of the engine.

2.3 Oxidizer System

The oxidizer system functioned properly, supplying LOX to the engine LOX pump inlet within the specified operating limits. Ullage pressure was maintained at a level adequate to insure engine pump net positive suction pressures (NPSH) above the minimum required to prevent pump cavitation.

The talkback switch of the chilldown shutoff valve failed to give an open indication when the valve opened, however, the LOX flowmeter did show a flow at this time.

2.4 Fuel System

The fuel system performed as designed and supplied LH2 to the engine LH2 pump inlet within the limits required for satisfactory engine performance. The chilldown shutoff valve talkback was erratic when the valve was in the open position and heat input during chilldown was higher than expected as discussed in section 8; however, the system performed satisfactorily. Analysis of the excessive heat input indicates that the problem could have been created by Beta I test stand facilities and is being investigated.

2.5 Pneumatic Control and Purge System

The pneumatic control and purge system performed satisfactorily throughout the acceptance firing. The helium supply to the system was adequate for both pneumatic valve control and purging; the regulated pressure was maintained within acceptable limits and all components functioned normally.

2.6 Propellant Utilization System

The PU system accomplished all the design objectives as listed in Douglas Report No. SM-47458A, *Saturn S-IVB-208 Stage Acceptance Firing Test Plan.*

2.7 Data Acquisition System

The data acquisition system performed satisfactorily throughout the acceptance firing. One hundred and seventy-seven measurements were active. Of these only one failed resulting in a measurement efficiency of 99.4 percent.

2.8 Electrical Power and Control Systems

The electrical power and control systems performed satisfactorily throughout the acceptance firing. All firing objectives were satisfied and all system variables operated within design limits.

2.9 Hydraulic System

The hydraulic system supplied pressurant fluid to the servo-actuators during the time the engine was successfully positioned and gimbaled. A leaking accumulator permitted GN_2 loss prior to the firing in excess of the allowable limits which caused engine-driven hydraulic pump overshoot pressure fluctuations. The system function to position the engine in response to guidance commands was not adversely affected. The accumulator-reservoir, P/N 1B29319-519 S/N 23 is being replaced before launch.

2.10 Flight Control System

The dynamic response of the hydraulic servo-thrust vector control system was measured while the J-2 engine was gimbaled during the acceptance firing. The performance of the pitch and yaw hydraulic servo control systems was found to be acceptable.

2.11 Structural System

Structural integrity of the stage was maintained during the vibration, temperature, and thrust load conditions of the acceptance firing. A post acceptance firing inspection of the stage revealed no debonding or other discrepancies resulting from the cryogenic loading and firing. A visual inspection of the LH_2 tank interior was made from the manhole; no discrepancies were noted,

2.11.1 Post S-IVB-503 Explosion Inspection

Following the explosion of the S-IVB-503 stage at the adjacent Beta III test stand, the S-IVB-208 stage exterior structure and LH2 tank interior were again inspected. No structural damage was detected.

2.12 Thermoconditioning and Purge System

The thermoconditioning and purge system functioned properly during the acceptance firing. All system temperatures and flowrates were maintained within design limits.

2.13 Reliability and Human Engineering

All functional failures of Flight Critical Items and Ground Support Equipment/Special Attention Items were investigated by Reliability Engineering. A Human Engineering evaluation was conducted in support of the acceptance firing and no significant man-machine problems were identified.

3. TEST CONFIGURATION

This section describes the stage and ground support equipment (GSE) deviations and modifications from the flight configuration affecting the acceptance firing. Additional details of specific system modifications are discussed in appropriate sections of this report. Details of the S-IVB-208 stage configurations are presented in Douglas Report No. 1B66532, *S-IVB-IB Stage End-Item Test Plan.*

Figure 3-1 is a schematic of the S-IVB-208 stage propulsion system and shows the telemetry instrumentation transducer locations from which the test data were obtained. The functional components are listed in table 3-1. Hardwire measurements are noted on the appropriate subsystem schematics included in this report. The propulsion system orifice characteristics and pressure switch settings are presented in tables 3-2 and 3-3. J-2 engine S/N 2062 was installed.

The propulsion GSE (figure 3-2) consisted of pneumatic consoles "A" and "B," two propellant fill and replenishing control sleds, a vacuum system console, and a gas heat exchanger.

3.1 Configuration Deviations

Configuration deviations required for the acceptance firing are discussed in Douglas Report No. SM-47458A, *Saturn S-IVB-208 Stage Acceptance Firing Test Plan.* Significant configuration changes to the stage and GSE are discussed in the following paragraphs.

3.1.1 Engine Restrainers

J-2 engine unlatch restrainer link kit, Model DSV-4B-618, was installed to restrain the engine during start transient side loads.

3.1.2 Quick Disconnects

The stage-mounted portions of the pneumatic and propellant umbilical quick disconnects were replaced by hardlines.

3.1.3 Engine Diffuser

A water-cooled converging diffuser, Model DSV-4B-639 engine bell extension service unit, was installed in the engine thrust chamber exit to reduce the nozzle area ratio and the probability of jet-separation-induced side loads.

3.1.4 Auxiliary Pressurization

An auxiliary propellant tank pressurization system was installed and was supplied from a GSE ambient helium source.

3.1.5 Propellant Fast Fill Sensors

Propellant loading fast fill sensors were installed on the instrumentation probes but were used in the indicating mode only.

3.1.6 Stage Vent and Bleed System

All stage propellant vent and bleed systems were connected to the facility vent system.

3.1.7 Forward Skirt Cooling

The forward skirt thermoconditioning system coolant was supplied by a Model DSV-4B-359 servicer, rather than by the flight source in the instrument unit.

3.1.8 Aft Interstage

The stage was mounted on a Model DSV-4B-540 dummy aft interstage instead of the flight interstage.

3.1.9 Fire Detection System

A resistance wire fire detection system was installed for monitoring critical areas of the stage, GSE, and facilities.

3.1.10 Gaseous Hydrogen Detectors

A gaseous hydrogen (GH2) leak detection system was installed for monitoring critical areas of the stage, GSE, and facilities.

3.1.11 Blast Detectors

Blast detectors were installed in the test area to monitor ranges of 0 to 25 psig overpressure.

3.1.12 Auxiliary Propulsion System

The flight auxiliary propulsion system (APS) modules were not installed. Instead, the Model 188B APS Simulators were connected to APS positions 1 and 2 to receive commands and close the control circuitry.

3.1.13 Telemetry System

Those telemetry channels that were left blank when various parameters were disconnected to be recorded by other means were either left as open channels or were simulated.

3.1.14 Hardwire Transducers

The Marshall Space Flight Center static firing measurement (Scope Change 1195A) program hardwire transducers were installed for the acceptance firing. These measurements will be removed before the stage leaves STC.

3.1.15 Forward Stage/Instrument Unit Interface

The instrument unit (IU) was not available at the Sacramento Test Center; therefore, the IU and S-IB electrical interfaces were simulated by GSE.

3.1.16 Electrical Umbilicals

The electrical umbilicals remained connected throughout the acceptance firing.

3.1.17 Instrumentation System

The stage data acquisition system was as defined in Douglas Drawing No. 1B43561, *Instrumentation Program and Components List, Saturn S-IVB-208*, except as called out in section 11.

3.1.18 Electrical Power System

The Model DSV-4B-170 battery power unit was used during the acceptance firing when stage systems were switched to internal power.

3.1.19 Secure Range Safety Command System

The engine cutoff command output from range safety system No. 1 and range safety system No. 2 was disconnected and stowed. Pulse sensors were attached to the output of the exploding bridgewire (EBW) firing units.

TABLE 3-1 (Sheet 1 of 3)
S-IVB-208 STAGE HARDWARE LIST

ITEM NO.	PART NO.	NAME
1	7851861-1	Disconnect, LH2 tank pressurization
2	1B65673-1	Valve, check, LH2 tank prepressurization line
3	1B53817-505	Valve, hand, 3-way, LH2 and LOX fill and drain valves, nonpropulsive vent and LH2 chilldown valve purge line
4	1B51361-1	Valve, check, LH2 fill and drain valve and nonpropulsive vent purge line
5	1B53817-505	Valve, hand, 3-way, LOX vent and relief valve purge line
6	7851823-503	Disconnect, ambient helium fill
7	1B63206-1	Orifice, ambient helium fill, 65 scfm
8	1B51361-1	Valve, check, control helium fill
9	1A57350-507	Module, control helium fill
10	1A49990-501	Sphere, control helium, 905 sci
11	1A48848-505	Disconnect, LH2 tank vent
12	1B66932-501	Disconnect, LH2 fill and drain
13	1B40622-505	Orifice, LH2 fill and drain valve purge line, 15 scim
14	1B66692-1	Module, actuation control, LH2 fill and drain valve
15	1B41065-1	Disconnect, common bulkhead vacuum system
16	1A48240-505	Valve, LH2 fill and drain
17	1B66932-501	Disconnect, LOX fill and drain
18	1B51361-1	Valve, check, LOX fill and drain valve purge line
19	1B40622-505	Orifice, LOX fill and drain valve purge line, 15 scim
20	1A48240-505	Valve, LOX fill and drain
21	1B66692-1	Module, actuation control, LOX fill and drain valve
22	1B57781-503	Module, cold helium fill
23	1B40824-503	Valve, check, cold helium fill line
24	1B42290-503	Module, LOX tank pressure control
25	7851844-501	Disconnect, cold helium fill and LOX tank prepressurization
26	1B40824-503	Valve, check, cold helium fill and LOX prepressurization line
27	1A49991-1	Plenum, LOX tank pressurization, 250 sci
28	7851830-517	Switch, pressure, LOX tank pressurization regulator backup, P/U 465 +20 -15 psia, D/O 350 +20 -15 psia
29	1B63046-513	Orifice, LOX tank pressurization, heat exchanger primary, 0.0318 in^2 effective area

TABLE 3-1 (Sheet 2 of 3)
S-IVB-208 STAGE HARDWARE LIST

ITEM NO.	PART NO.	NAME
30	1B63047-513	Orifice, LOX tank pressurization, heat exchanger bypass, 0.02265 in^2 effective area
31	1A49958-517	Disconnect, thrust chamber jacket purge and childown
32	1B40622-501	Orifice, LOX tank sensing line purge, 1 scfm
33	1B43657-509	Module, pneumatic power control
34	1A48857-1	Plenum, control helium, 100 sci
35	1B55200-505	Module, LH2 tank pressure control
	1B64443-505	Orifice, normal flow, 0.0455 in^2 effective area
	1B64443-505	Orifice, control flow, 0.0778 in^2 effective area
	1B64443-505	Orifice, step flow, 0.1392 in^2 effective area
36	1B51361-1	Valve, check, LH2 nonpropulsive vent purge line
37	1B40622-501	Orifice, LH2 nonpropulsive vent purge line, 1 scfm
38	1B59265-1	Orifice, nonpropulsive vent, 2.180 in. dia
39	1B59265-1	Orifice, nonpropulsive vent, 2.180 in. dia
40	7851860-541	Switch, pressure, LH2 flight control, P/U 29.5 psia, D/O 26.5 psia
41	7851860-537	Switch, pressure, LH2 prepressurization and ground fill, P/U 34 psia,
	1A48257-509	D 031 psia min
42	1A67005-507	Switch, pressure, LH2 tank orbital vent initiation, P/U 35.25 $\pm$0.75 psia, D/O 31 psia min
43	DELETED	
44	1B53817-505	Valve, 3-way, LH2 tank pressure switch shutoff
45	1A49988-1	Valve, directional control, LH2 vent
46	1A49591-527	Valve, relief, LH2 tank, crack 40 psia max, reseat 37 psia min
47	1A48257-509	Valve, vent and relief, LH2 tank, crack 39 psia max, reseat 36 psia min
48	1A48858-1	Sphere, storage, cold helium (6 each)
49	1B58100-1	Probe, LH2 temperature sensor
50	1A48431-501	Probe, LH2 mass sensor
51	1A79603-505	Probe, LOX temperature sensor
52	1A48430-507	Probe, LOX mass sensor
53	1A49421-501	Pump, LH2 chilldown
54	1A48854-1	Orifice, LOX chilldown pump purge line, 37 scim
55	1A58347-505	Module, LOX chilldown pump purge
56	1A49423-505	Pump, LOX chilldown
57	1A49964-501	Valve, check, LOX chilldown return line

TABLE 3-1 (Sheet 3 of 3)
S-IVB-208 STAGE HARDWARE LIST

ITEM NO.	PART NO.	NAME
58	7851847-535	Switch, pressure, LOX chilldown pump purge regulator backup, P/U 53 psia max, D/O 49 psia min
59	114-109 (PESCO)	Valve, relief, LOX chilldown pump motor container, crack and reseat 65 to 85 psia
60	1A67913-1	Valve, vent, LOX chilldown pump motor container
61	1A49965-521	Valve, shutoff, LOX chilldown line
62	1A89104-509	Flowmeter, LOX chilldown line
63	1A87749-1	Strainer, LOX chilldown pump discharge
64	1A59968-509	Prevalve, LOX
65	1B53817-505	Valve, 3-way, LOX tank pressure switch shutoff
66	DELETED	
67	1B66692-1	Module, actuation control, directional valve, LH2 vent
68	1B66692-1	Module, actuation control, LH2 vent and relief valve
69	7851847-533	Switch, LOX prepressurization, flight, and ground fill control, P/U 40 psia max, D/O 37 psia min
70	1A49964-501	Valve, check, LH2 chilldown return line
71	1A49968-507	Prevalve, LH2
72	1A49965-519	Valve, shutoff, LH2 chilldown pump discharge
73	1B52985-501	Strainer, LH2 chilldown pump discharge
74	1B53920-503	Valve, check, LH2 chilldown pump discharge
75	1A89104-507	Flowmeter, LH2 chilldown pump discharge
76	1B66692-1	Module, actuation control, prevalves and chilldown valves
77	1B40622-507*	Orifice, LH2 chilldown shutoff valve purge line, 14 scfm
78	1B51361-1	Valve, check, LOX vent and relief valve purge line
	DELETED	
80	1B63206-1	Orifice, flow, LOX vent and relief valve purge line, 65 scfm
81	1A49590-513	Valve, relief, LOX tank, crack 45 psia, reseat 42 psia
82	1A48312-501	Valve, vent and relief, LOX tank, crack 44 psia, reseat 41 psia
83	1B66692-1	Module, actuation control, LOX vent and relief valve
84	1B56804-1	Module, engine purge control
85	1A67002-509	Switch, pressure, engine purge regulator backup, P/U 130 psia min, D/O 105 psia min
86	1A49958-521	Disconnect, engine start sphere vent and relief valve drain
87	1A49958-515	Disconnect, engine control helium sphere fill
88	1A49958-523	Disconnect, engine start sphere fill

* Flight orifice--for acceptance tests, purge function is supplied by facility orifice P/N S2253887-4C-.032, 65 scfm at 1,600 psia.

TABLE 3-2 (Sheet 1 of 3)
S-IVB-208 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

ITEM*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (IN.^{2})
	Stage			
7	Ambient helium fill	65 scfm	--	Sintered
13	LH2 fill and drain valve purge line	15 scim at 3,200 psid	--	Sintered
19	LOX fill and drain valve purge line	15 scim at 3,200 psig	--	Sintered
29	LOX tank pressurization system heat exchanger outlet	0.219 in. dia	0.845	0.0318
30	LOX tank pressurization system heat exchanger bypass	0.185 in. dia	0.844	0.02265
32	LOX tank sensing line purge	1 scfm at 3,200 psig	--	Sintered
35	LH2 tank pressurization module			
	Undercontrol**	0.250 in. dia	0.927	0.0455
	Overcontrol**	0.221 in. dia	0.890	0.0778
	Step**	0.3124 in. dia	0.848	0.1392
37	LH2 tank nonpropulsive vent purge line	1 scfm at 3,200 psid	--	Sintered
38-39	LH2 tank nonpropulsive vent(2)	2.180 in. dia	NC	--
54	LOX chilldown pump purge line	37 scim at 475 psid	--	Sintered
55	LOX chilldown pump purge module	0.00166 lbm/sec at 475 psig IN and 85 psig OUT		
77	LH2 chilldown valve purge line+	14 scfm at 3,000 psid	--	Sintered
80	LOX tank vent and relief valve purge line	65 scfm at 3,100 psid	+	0.00043

* Indicates location on figures 3-2 and 3-3.

** Discharge coefficient and effective area are calculated for overcontrol and step orifices in successive combination with the undercontrol orifice.

\+ Flight orifice--for acceptance testing, purge function is supplied by facility orifice of 65 scfm at 1,600 psia.

TABLE 3-2 (Sheet 2 of 3)
S-IVB-208 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

ITEM*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA ($IN.^2$)
84	Engine pump purge module	0.00166 lbm/sec at 475 psig IN and 85 psig OUT	--	0.00023
	Console A			
A9538	LH2 tank repressurization supply	Union	--	--
A9537	Pressure switch checkout--high pressure	0.032 in. dia	--	--
A9536	Pressure switch checkout--low pressure	1.2 scfm	--	Sintered
A9535	LH2 tank and umbilical purge supply	0.260 in. dia	0.88	0.04675
--	All console A stage bleeds	Variable	--	--
A9515	Pressure actuated valve and mainstage pressure switch supply	1.2 scfm	--	Sintered
A9533	LH2 system checkout supply	1.2 scfm	--	Sintered
A9534	LOX system checkout supply	5.0 scfm	--	Sintered
A9539	Console GN2 inerting supply	0.013 in. dia	--	--
A9526	J-box inerting supply	0.013 in. dia	--	--
	Console B			
--	All console B stage bleeds	Variable	--	--
A9529	LOX tank and umbilical purge system	0.305	--	--
--	Turbine start sphere supply	Union	--	--
A9552	Turbine start sphere supply vent	0.081 in. dia	0.93	0.00479
A9528	Thrust chamber jacket purge and chilldown system	0.072 in. dia	0.89	0.00362
A9525	Engine control sphere supply	0.125 in. dia	0.84	0.00965

* Indicates location on figures 3-2 and 3-3.

TABLE 3-2 (Sheet 3 of 3)
S-IVB-208 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

ITEM*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (IN.^{2})
A9527	LH2 tank prepressurization supply	0.162 in. dia	0.80	0.01649
A9348	Console GN2 inerting supply	Manifold	--	--
A9540	J-box inerting supply	0.013 in. dia	--	--
A9550	Engine control sphere supply vent	--	--	--
--	LOX tank prepressurization supply	0.096 in. dia	0.94	0.00680

* Indicates location on figures 3-2 and 3-3.

TABLE 3-3
S-IVB-208 PRESSURE SWITCHES

PARAMETER	PART NO.	PRESSURE (psia)					
		SPECIFIED		PRETEST		POST-TEST	
		PICKUP	DROPOUT	PICKUP	DROPOUT	PICKUP	DROPOUT
LH2 TANK							
Flight control	7851860-541	30.0 max	26.5 min	28.84	26.84	29.04	27.01
Prepressurization and ground fill valve control	7851860-537	34.5	30.8	33.23	31.27	33.43	31.39
Orbital vent	7851860-543	35 ±1	30.5	35.53	31.40	35.48	31.75
LOX TANK PRESSURIZATION SYSTEM							
LOX prepress, flight control, and ground fill valve control	7851847-533	41.0 max	36.5 min	40.33	38.09	40.03	37.71
LOX tank regulator backup	7851830-517	467.5 ±23.5	352.5 ±23.5	463.4	355.9	461.6	353.7
PNEUMATIC CONTROL SYSTEM							
Power control module	7851830-521	600 ±21	490 ±31	601.0	500.4	598.7	499.3
LOX chill pump motor container	7851847-535	54 max	49 min	52.6	49.9	52.78	50.13
Engine pump purge	1A67002-509	130 max	105 min	124.0	106.3	129.83	110.83
J-2 ENGINE							
Mainstage OK No. 1	PS-5874A500	515 ±36	PU minus 62.5 ±43.5	517.53	448.92	527.56	458.11
Mainstage OK No. 2	PS-5784A500	515 ±36	PU minus 62.5 ±43.5	506.16	440.86	511.36	442.49

NOTE: All pressures listed are the average of three actuations.

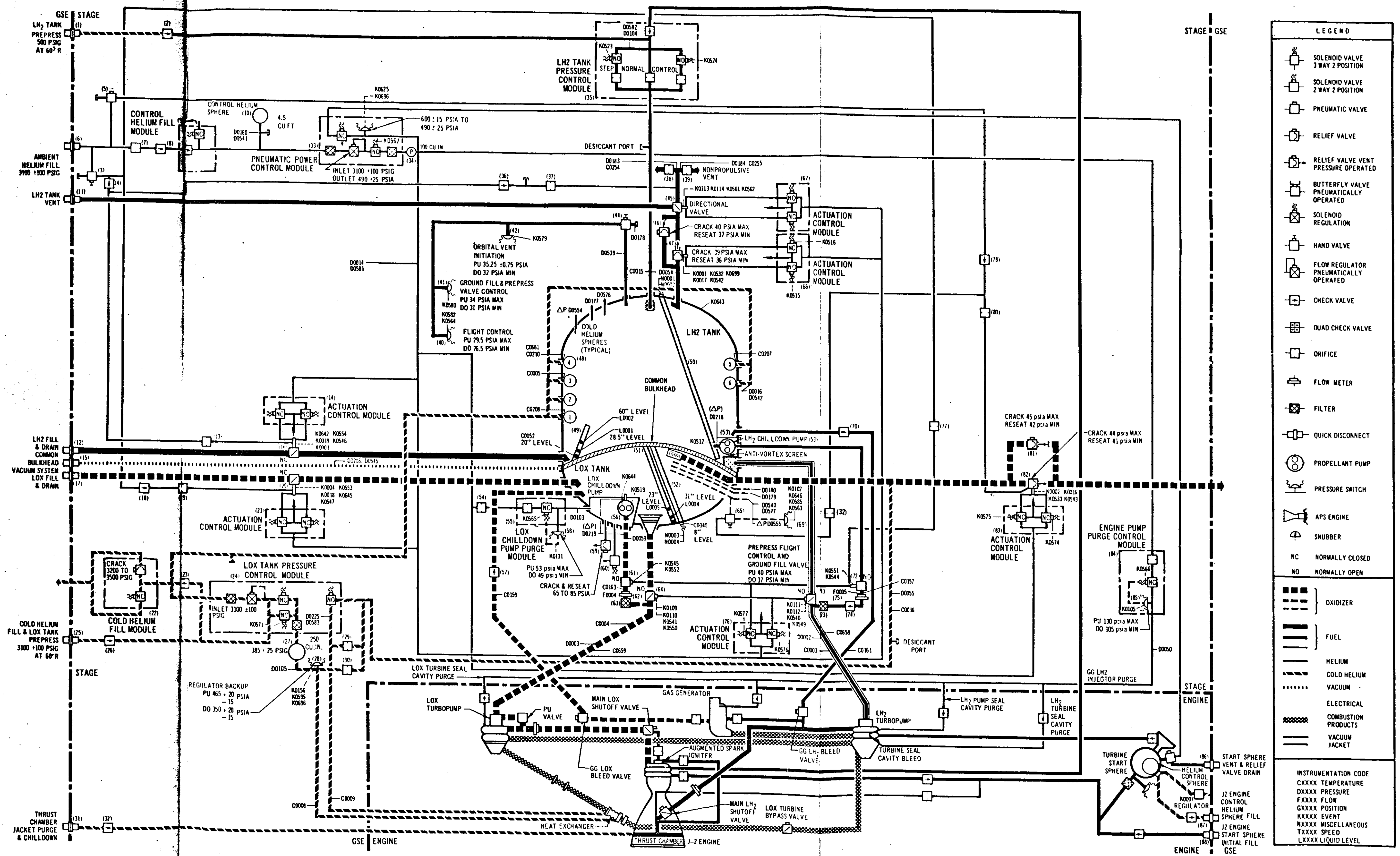

Figure 3-1. Propulsion System Configuration and Instrumentation

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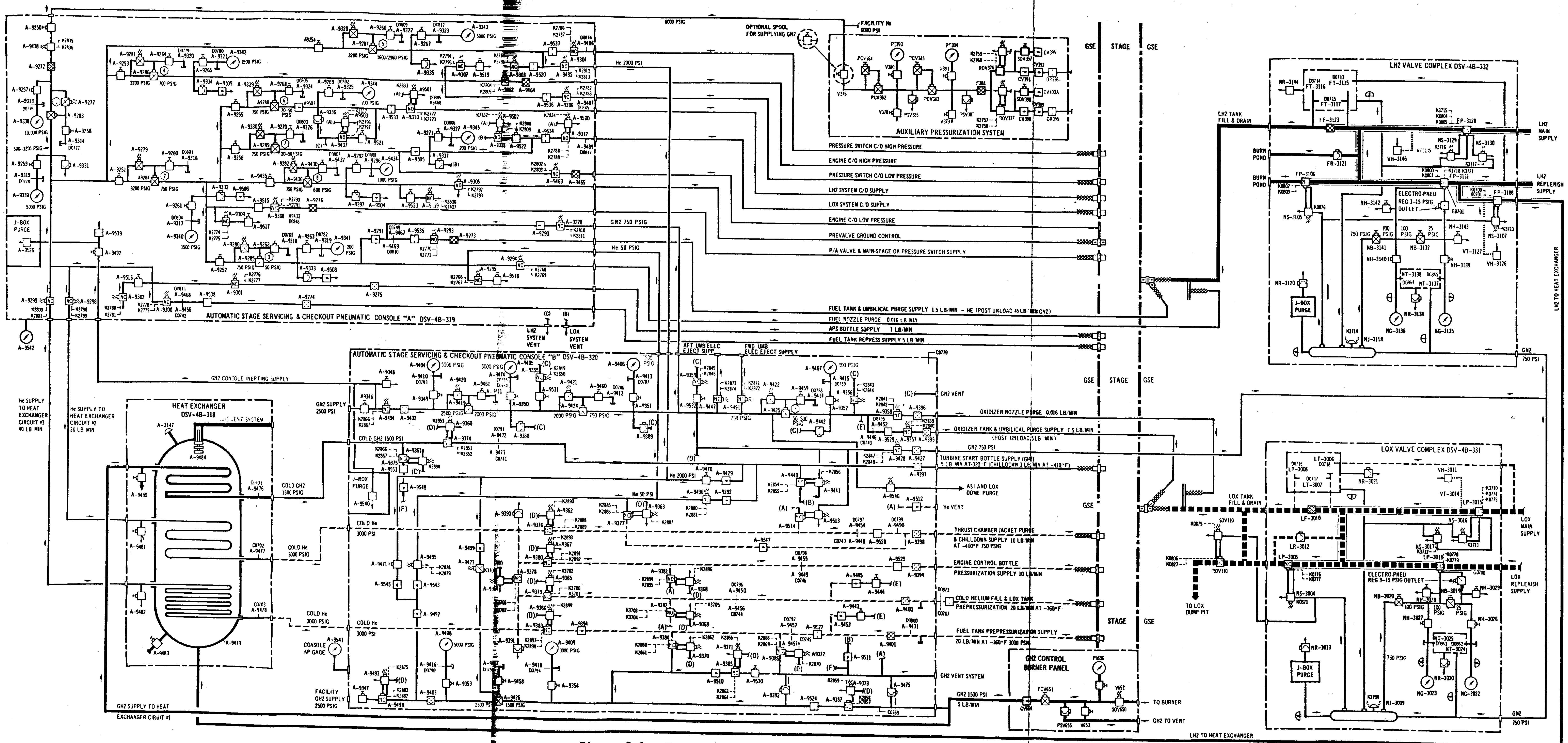


Figure 3-2. Facility Propellant and Pneumatic Loading System

4. COUNTDOWN OPERATIONS

The S-IVB-208 stage acceptance firing was successfully accomplished during CD 614076 on 12 January 1967. All phases of the acceptance firing countdown are reviewed and evaluated in the following paragraphs, which include discussions of the prefiring checkout, propellant loading, and ground support and facility operation.

4.1 Countdown 614076

CD 614076 was initiated on 11 January 1967 and was completed the following day with a satisfactory stage acceptance firing. The countdown was performed with only minor problems encountered; all problems were resolved without a delay in countdown time. The LOX and LH2 chilldown shutoff valves open talkbacks were erroneous and erratic during the countdown; however, the operation of the valves was verified after the chilldown pumps were cycled. LH2 and LOX loading were nominal. The propellant tank relief valve checks were performed satisfactorily; the stage pneumatic systems were pressurized, and the automatic terminal count was initiated. The automatic sequence was satisfactory and resulted in a successful mainstage firing of 426.6 sec. Significant countdown times are presented below:

Event	Time
Simulated liftoff (T_0)	1209:46.0 PST
Engine Start Command (ESC)	T_0 +150.270 sec
Engine Cutoff Command (ECC)	T_0 +576.873 sec

4.2 Checkout

The modifications, procedures, and checkouts performed for the acceptance firing were initiated on 5 December 1966, upon receipt of the stage at the Sacramento Test Center, and were continued through 10 January 1967 when the stage was ready for the acceptance firing. The handling and checkout procedures that were used for the prefiring and postfiring checkouts are described in Douglas Report No. DAC 56499, *Narrative End Item Report on Saturn S-IVB-208*, dated April 1967.

The integrated systems test was completed on 29 December 1966 to check out the automatically controlled equipment of the stage, pneumatic consoles, and propellant sleds. The simulated acceptance firing was satisfactorily performed on 5 January 1967 and verified the countdown procedure.

4.3 Cryogenic Loading

The S-IVB-208 stage was successfully loaded with LOX, LH2, and cold helium. Satisfactory temperature and pressure levels were attained in all systems, although anomalies with the No. 1 LH2 depletion sensor and the LOX chilldown shutoff valve were noted during LH2 loading.

4.3.1 LOX Loading

The LOX loading preparations were conducted as specified in Task 41 of the *Countdown Manual*, and computer controlled loading operations were initiated. Loading was satisfactorily accomplished to the 100 percent level (data are presented in figure 4-1) without incident. After the 100 percent LOX level was reached, loading was continued manually to the top of the active element of the PU probe, and the tank was pressurized to 25 psia for 3 min. to obtain calibration data.

4.3.2 LH2 Loading

The LH2 loading preparations were completed and the loading operation was initiated as specified in Task 42 of the *Countdown Manual*. The loading was satisfactorily completed. Although anomalies were noted in two external systems, no interruption of the loading was required. Loading data are presented in figure 4-2.

During the loading, the LH2 depletion sensor No. 1 cycled intermittently from start of loading for 26 min. Normal operation was observed after this time. This problem is being investigated.

At 70 percent, the chilldown shutoff valves were commanded open, but the LOX valve talkback indicated the valve remained closed. During the tank relief test, the LH2 chilldown shutoff valve gave a momentary erratic closed indication. After completion of the relief test, the chilldown pumps were turned on, and subsequent flow indicated that the valves were actually open and that the talkback indications were faulty.

The problem has been identified as a microswitch and seal problem and a corrective redesign is in process. Until a redesign is implemented, however, a repetition of this problem should not be considered unusual.

4.3.3 Cold Helium Loading

Cold helium was loaded after the completion of LH2 loading. Satisfactory temperatures and pressures were obtained. Data are presented in table 4-1 and figure 4-3.

4.4 GSE Performance

4.4.1 Helium Supply System

The helium supply system functioned adequately. Propellant tank pre-pressurization, thrust chamber chilldown, and loading of the cold helium spheres and the stage and engine control sphere were all satisfactorily accomplished. Data are presented in figures 4-4 through 4-7.

4.4.2 GH2 Supply System

The GH2 supply system performed adequately. Start sphere chilldown and loading were satisfactorily accomplished. At engine start command, the engine start sphere conditions were within the required limits. Data are presented in figure 4-5.

4.5 Terminal Count

The major events of the terminal count were engine conditioning and final replenishing and prepressurization of the propellant tanks. They included final addition of helium to the cold helium spheres and the stage pneumatic control sphere; chilldown of the thrust chamber, engine start sphere, and engine pumps; and pressurization of the start sphere.

The terminal count started with the automatic sequence at T_0 -25 min and proceeded through the scheduled events without incident. The final portion of the terminal count commenced with the initiation of propellant tank prepressurization at T_0 -165 sec; final propellant replenishing was completed by T_0 -54 sec. Cold helium sphere fill was terminated at T_0 -4.8 sec and engine pump purges were terminated at T_0 +89.5 sec, approximately as planned.

4.6 Holds

All problems were resolved without a delay in countdown time.

4.7 Atmospheric Conditions

The weather was fairly mild, although cool during the final portions of the acceptance countdown. Conditions at specific times are presented below:

Time (PST)	0700	0900	1200	1300
Wind speed (knots)	6	7	8	7
Wind direction (deg)	340	350	340	360
Barometric pressure (in. Hg)	30.02	30.05	29.97	29.97
Ambient temperature (deg F)	43	44	57	59
Dew point (deg F)	83	86	55	50

TABLE 4-1
COLD HELIUM LOADING DATA

S-IVB STAGE	COUNTDOWN	INITIAL PRESSURE (psia)	TIME* TO ACHIEVE 3,000 PSIA OR STABLE PRESSURE (sec)	TIME* TO ACHIEVE 50 DEG R (sec)	PRESSURE AT T_0 (psia)	TEMPERATURE AT T_0 (deg R)	LOADED MASS (lbm)
201	614040	1,500	200	900	3,200	40.0	342
	614047	750	400	860	3,200	40.4	370
202	614048	760	500	920	3,190	39.5	371
	614050	785	670	1,030	3,100	38.5 (H/W) 41.5 (T/M)	346
203	614054	DNA	DNA	DNA	DNA	DNA	DNA
	614055†	734-1,415	N/A-1,153	716-664	N/A-2,990	N/A-41	334
	614056	750	756	940	3,000	42.0	330
204	614059	730	300	1,000	3,165	41.2	337
501	614061	645	550	1,080	3,185	40.0	346
	614063	750	350	1,020	3,155	40.0	340
205	614064	830	354	914	3,050	39.5	338
502	614067	900	340	1,007	3,150	40.2	336
206**	614070	960	300/2,860 psia	1,265	3,020	40.0	251
207**	614074	1,485	230/2,990 psia	700	3,060	39.0	254
208**	614076	1,405	300/2,900 psia	900	3,046	40.0	254

* Elapsed time after start of cold helium loading

DNA Data not available

† After the cold helium spheres attained 2,920 psia, they were vented to 1,500 psia to permit repairs to the gas heat exchanger relief valves. The spheres were then repressurized.

** S-IVB-206 and subsequent stages utilized only six cold helium spheres

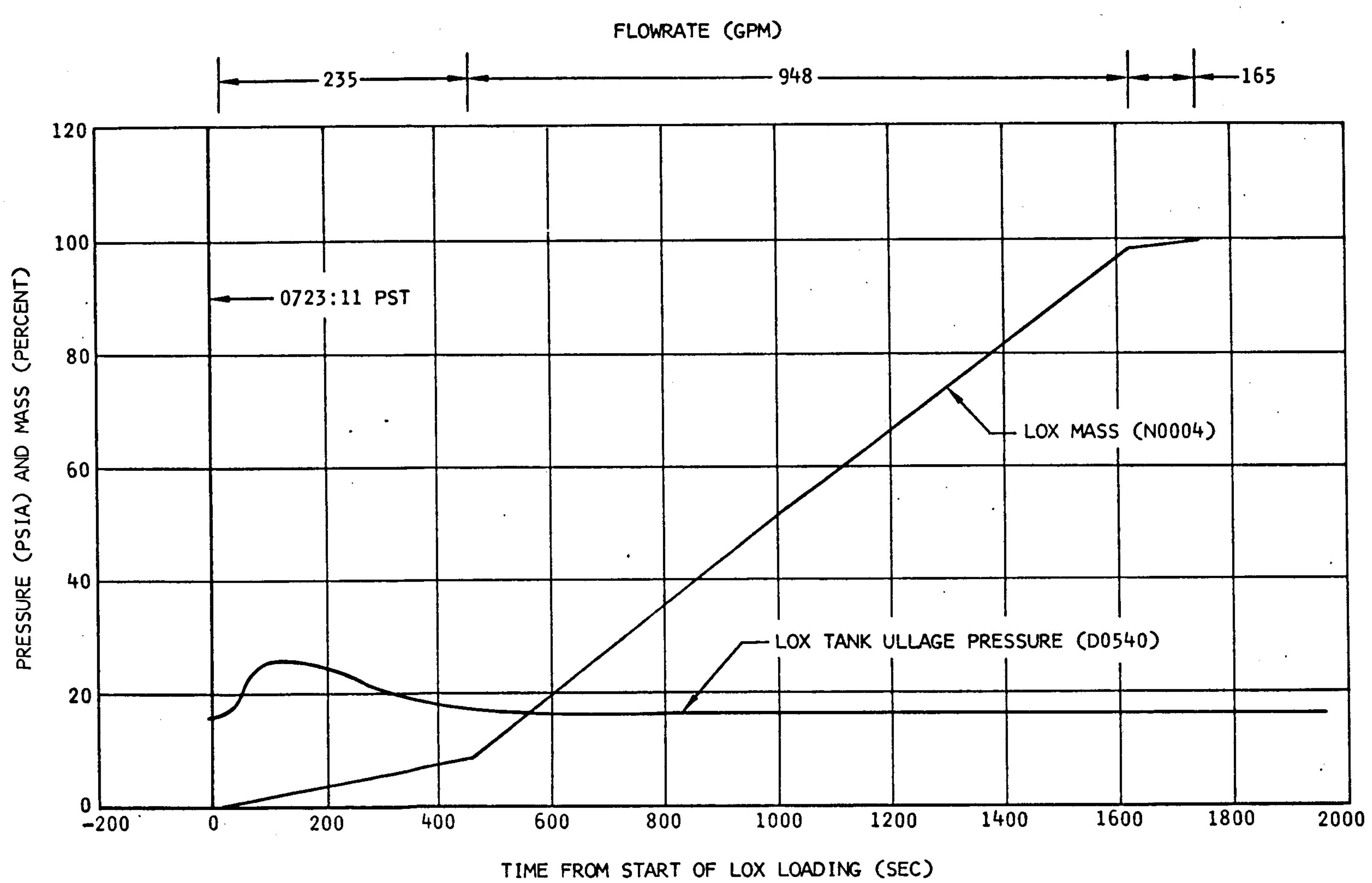


Figure 4-1. LOX Tank Loading

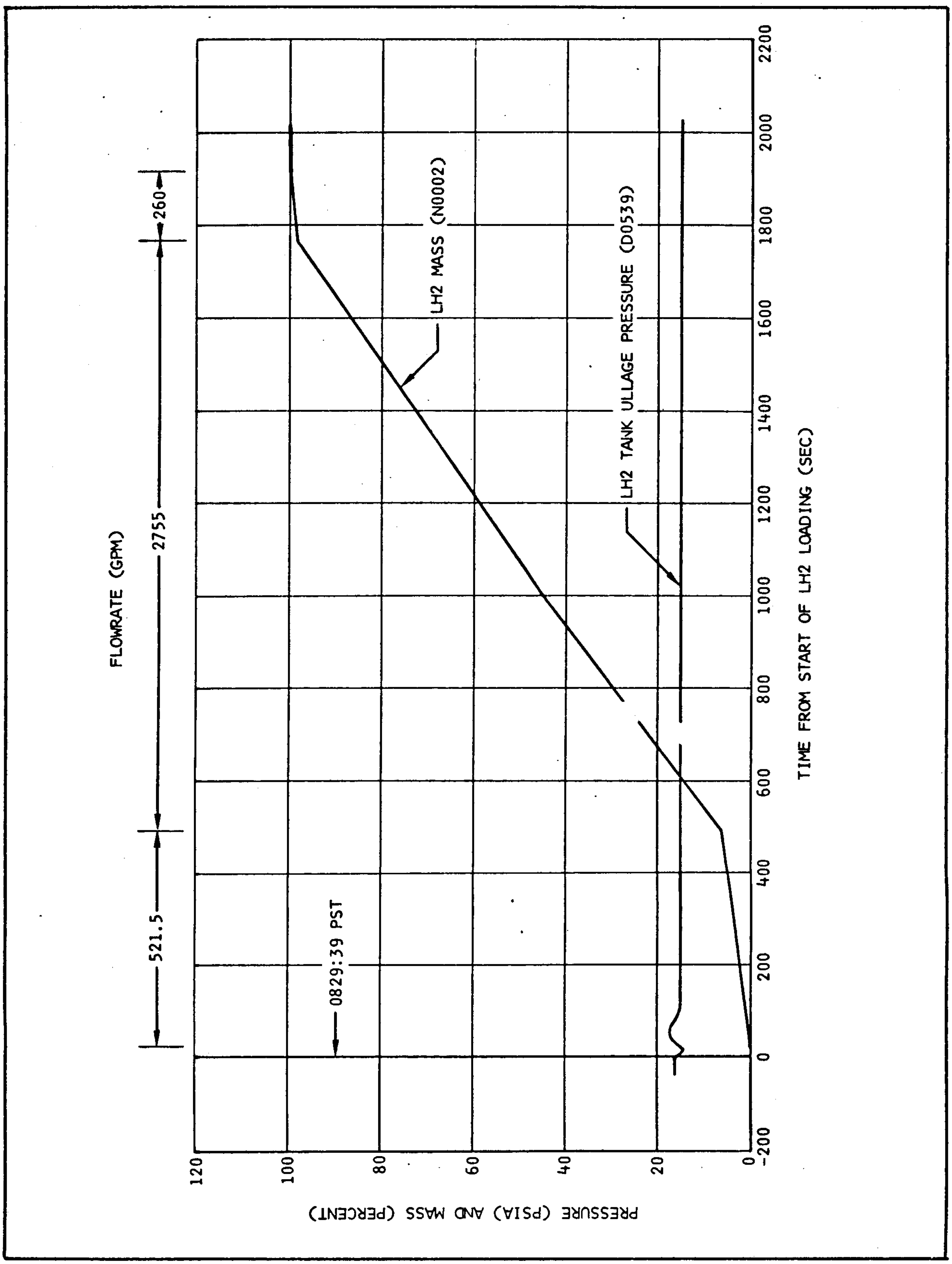


Figure 4-2. LH2 Tank Loading

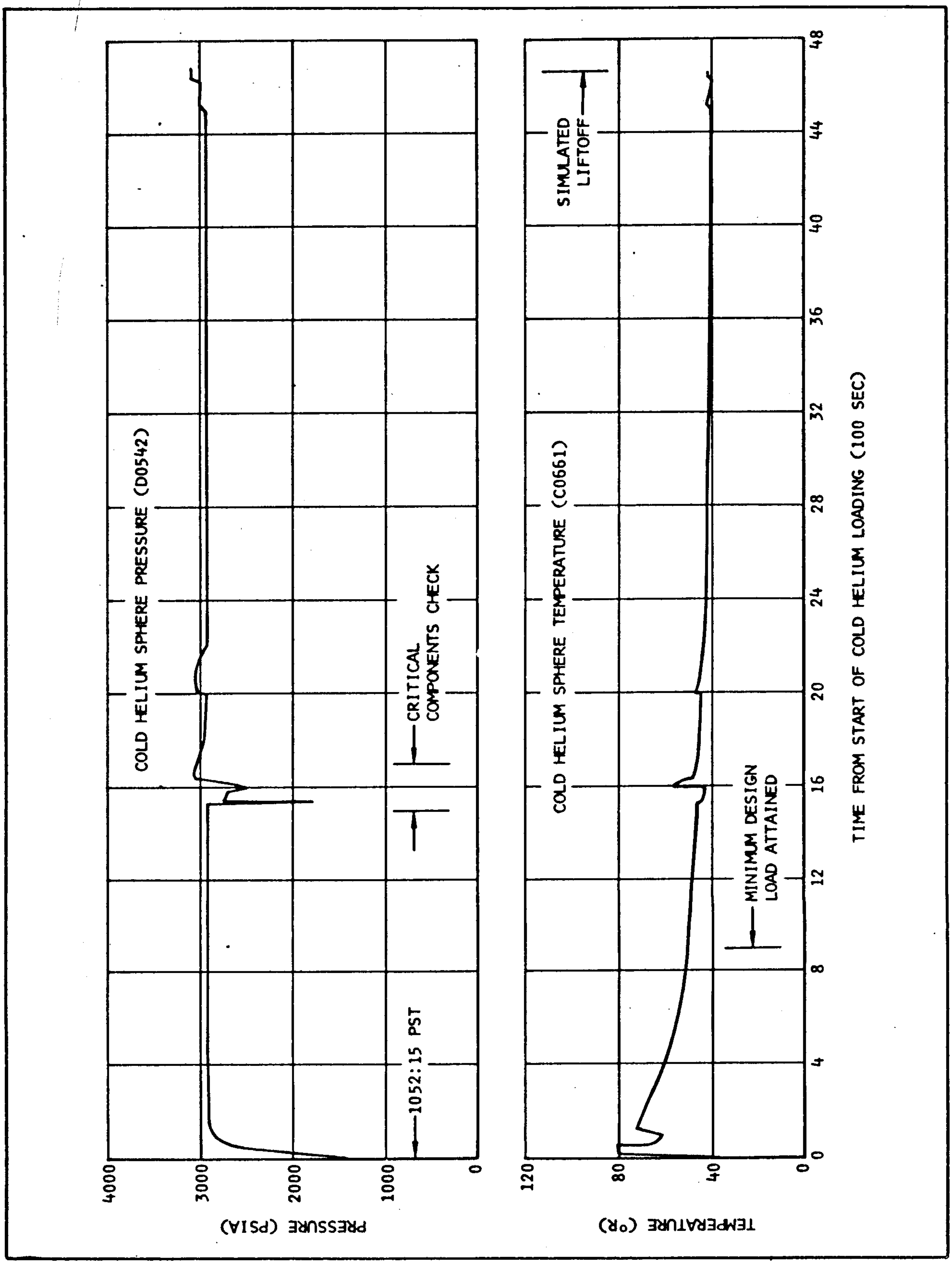


Figure 4-3. Cold Helium System Loading

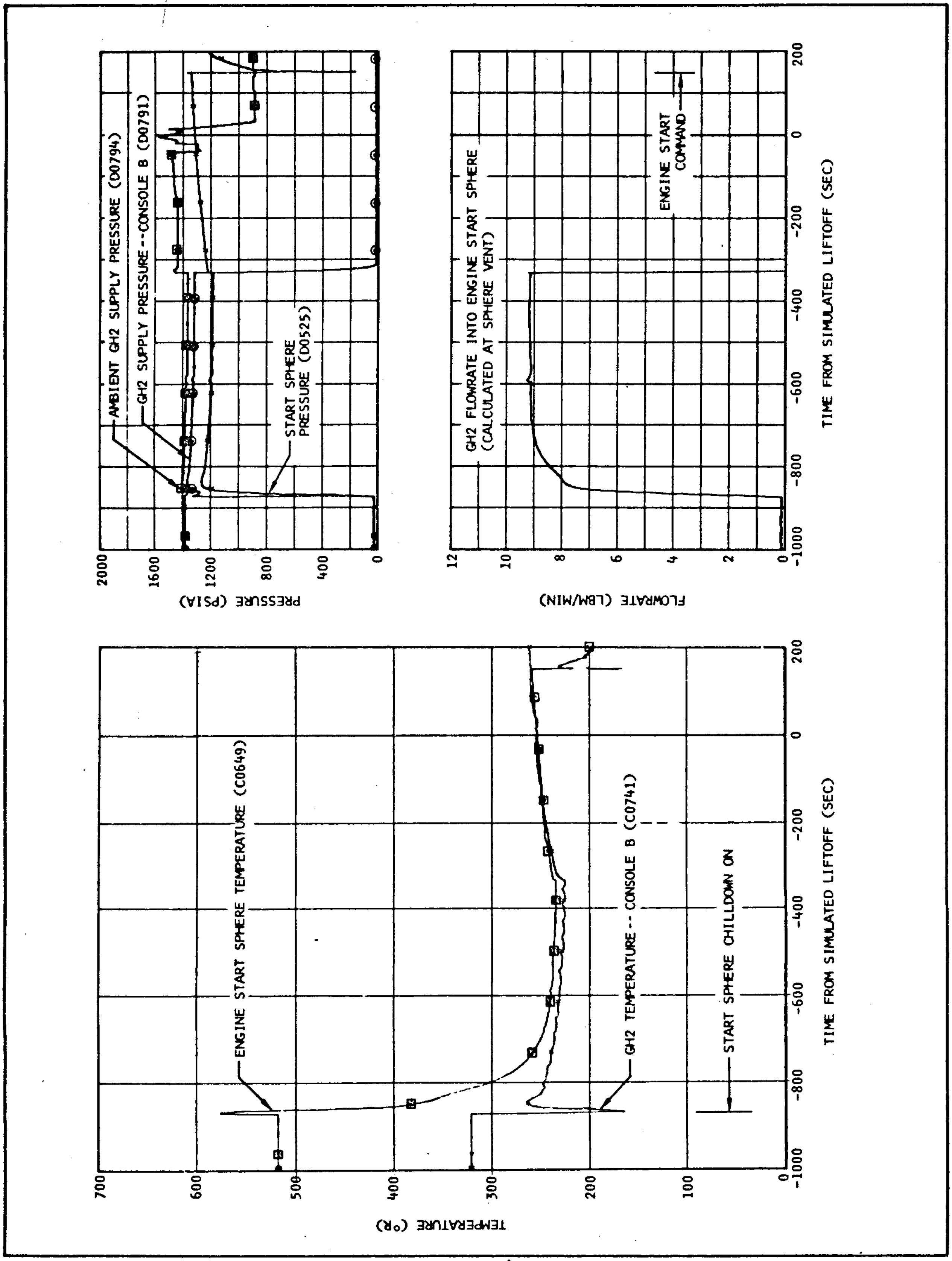


Figure 4-4. GSE Performance During Engine Start Sphere Childown and Loading

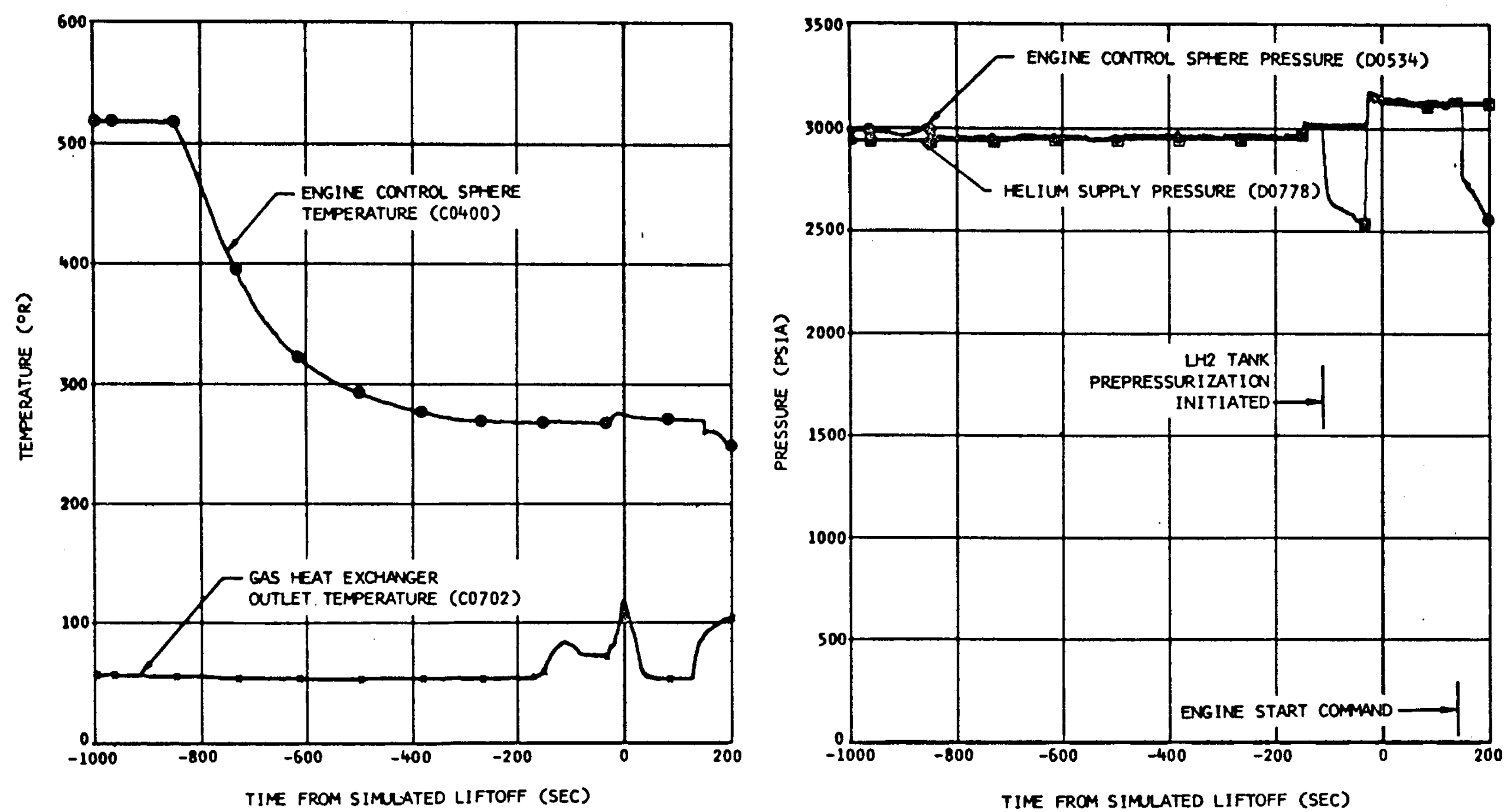
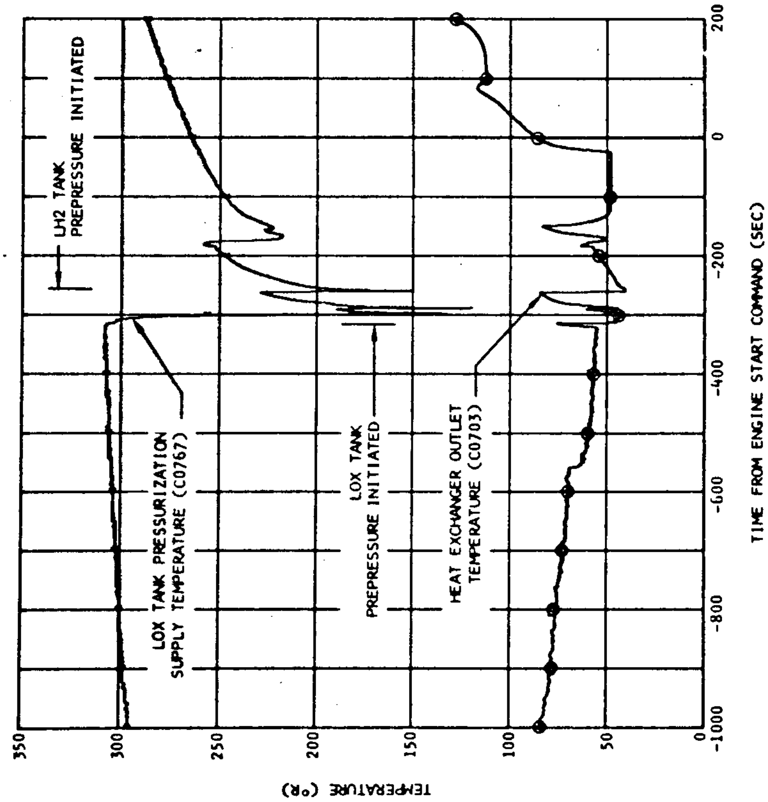


Figure 4-5. GSE Performance During Engine Control Sphere Loading



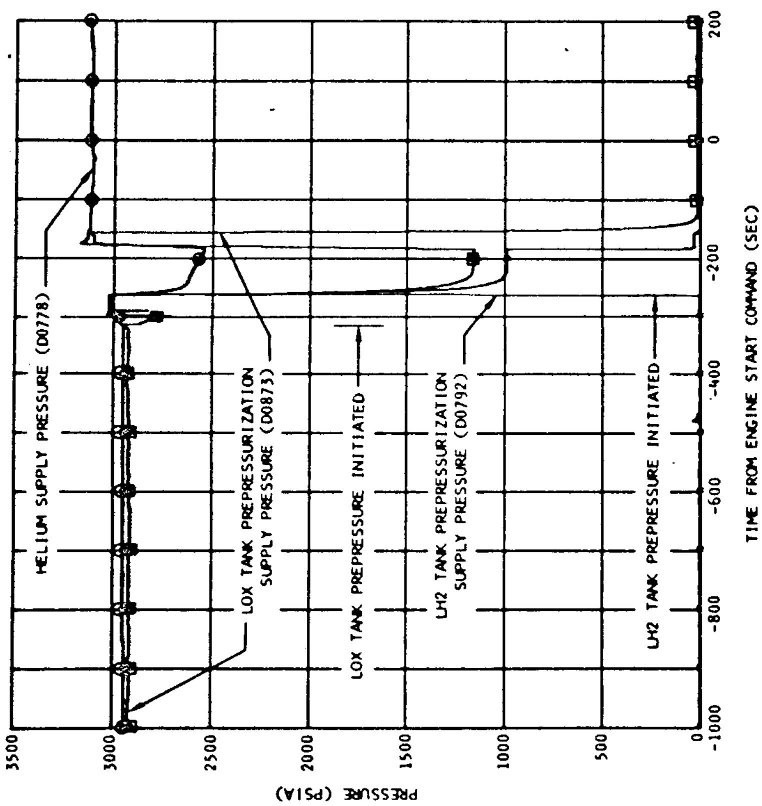


Figure 4-6. GSE Performance During LOX and LH2 Tank Prepressurization

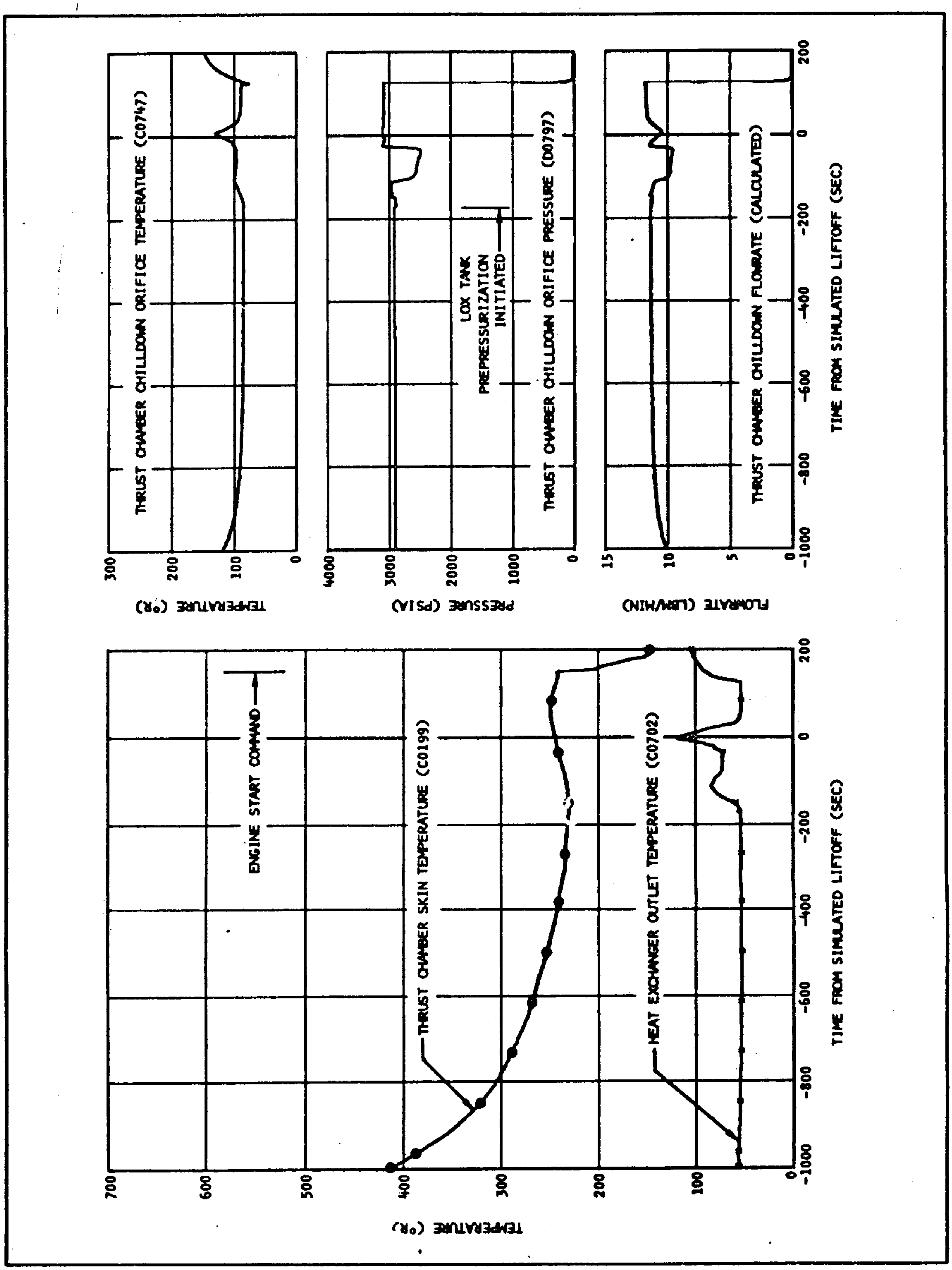


Figure 4-7. GSE Performance During Thrust Chamber Chilldown

5. SEQUENCE OF EVENTS

The S-IVB-208 stage acceptance firing sequence of events is presented in table 5-1. Event times from three data sources are included in the table. These sources were Digital Events Recorder (DER/CAT 57), PCM/FM Sequence (CAT 42), and PCM/FM Digital Tabulation (PCM/TAB/CAT 45). Accuracies of the listed events are as follows:

DATA SOURCE	ACCURACIES
Digital Events Recorder (DER/CAT 57)	+0, -1 ms
PCM/FM	
Discrete Bi-Level (CAT 42)	+0, -9 ms
Digital Tabulation (CAT 45)	
Prime	+0, -9 ms
Submultiplex	+0, -84 ms

TABLE 5-1 (Sheet 1 of 7)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)		PCM/FM DIGITAL TABULATION (CAT 45)	
		MN	TIME*	MN	TIME*	MN	TIME*
Auxiliary Hydraulic Pump On	28		-695.522				
Auxiliary Hydraulic Pump Coast Mode Off	31		-673.699				
LOX Childown Pump On	22		-599.705				
LH2 Childown Pump On	58		-596.525				
**Engine Pump Purge Control Valve Open Command	24		-92.694				
Internal Power Transfer (micro switch failure)							
PWR Aft Bus #1 INT XFER		K0622	-26.794				
PWR Aft Bus #2 INT XFER		K0623	-26.496				
PWR FWD Bus INT XFER		K0639	-26.240				
Simulated Liftoff T_0							
Ullage Rocket Chg On Command	54	K3890	141.393				
EBW Charge 1-1						M32	142.0
EBW Charge 1-2						M33	142.0
EBW Charge 2-1						M34	142.0
EBW Charge 2-2						M35	142.0
EBW Charge 3-1						M36	142.0

*Time from simulated liftoff (T_0)

**+0, -40 msec delay due to GSE circuit configuration

TABLE 5-1 (Sheet 2 of 7)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)		PCM/FM DIGITAL TABULATION (CAT 45)	
		MN	TIME*	MN	TIME*	MN	TIME*
EBW Charge 3-2						M37	142.0
Ullage Rocket Fire Command	56	K3890	145.595				
EBW Fire 1-1				K143	145.677	M32	146.0
EBW Fire 1-2				K144	145.677	M33	146.0
EBW Fire 2-1				K145	145.685	M34	146.0
EBW Fire 2-2				K146	145.685	M35	146.0
EBW Fire 3-1				K147	145.685	M36	146.0
EBW Fire 3-2				K148	145.685	M37	146.0
Prevalve Open Command		K576	146.394				
LH2 Prevalve Open		K540	148.589	K111	148.577		
LOX Prevalve Open		K541	148.686	K109	148.744		
LH2 Childown Pump Off Command	59	K3890	149.600**				
Engine Cutoff Off Command	13	K3890	149.493				
Engine Cutoff Command On (Dropout)		K418	149.493	K140	149.552		
Childown Pump Discharge Valve Closed Command		K577	568.464				
LH2 Childown Pump Off		K512	***				
LOX Childown Pump Off Command	23	K3890	149.700**				
LOX Childown Pump Off		K519	***				

*Time from simulated liftoff (T_0)
**Time obtained from GSE oscillograph
***DER failure

TABLE 5-1 (Sheet 3 of 7)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)		PCM/FM DIGITAL TABULATION (CAT 45)	
		MN	TIME*	MN	TIME*	MN	TIME*
LOX Childown Valve Closed		K552	micro switch failure				
LH2 Childown Valve Closed		K551	micro switch failure				
Engine Start Command	9	K3890	150.845				
Thrust Chamber Spark System On		K10	150.273	K10	150.275		
Gas Generator Spark On		K11	150.273	K11	150.275		
Helium Control Solenoid Energized		K531	150.273	K7	150.275		
Engine Ready Signal Off		K530	150.276	K12	150.335		
Engine Start On (ESC)		K556	150.273				
Ignition Phase Control Solenoid Energ		K535	150.273	K6	150.275		
Main Fuel Valve Closed (Dropout)		K632	150.326				
Main Fuel Valve Open		K118	150.376	K118	150.419		
Ignition Detected		K537	150.847	K8	150.650		
Engine Start Off Command	27	K3890	150.845				
Engine Start Off		K556	150.848				
Start Tank Discharge Valve Close (Dropout)		K695	151.059				
Start Tank Discharge Valve Open		K122	151.477	K122	151.169		
LOX Tank Flight Pressure System On Command	103	K3890	151.133				

*Time from simulated liftoff (T_0)

TABLE 5-1 (Sheet 4 of 7)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)		PCM/FM DIGITAL TABULATION (CAT 45)	
		MN	TIME*	MN	TIME*	MN	TIME*
Mainstage Control Solenoid Energized		K538	151.352	K5	151.359		
Main Oxidizer Valve Closed (Dropout)		K633	151.458				
Gas Generator Valve Closed (Dropout)		K631	151.457				
Start Tank Discharge Valve Open (Dropout)		K122	151.457	K122	151.502		
Gas Generator Valve Open		K117	151.574	K117	151.585		
Oxidizer Turbine Bypass Valve Open (Dropout		K124	151.592	K124	151.677		
Oxidizer Turbine Bypass Valve Closed		K125	151.772	K125	151.844		
Mainstage Pressure Switch Depress B (Dropout)		K573	152.804	K159	152.861		
Mainstage Pressure Switch Depress A (Dropout)		K572	152.797	K158	152.861		
Mainstage OK		K14	**	K14	152.835		
Engine Burn #1 On Command	68	K3890	153.278				
Engine Burn #1 On (LH2 Tank Step Press. Cont Sol)		K523	153.286				
Main Oxidizer Valve Open		K120	153.616	K120	153.669		
Gas Generator Spark System Off		K11	154.632	K11	154.634		
Thrust Chamber Spark System Off		K10	154.634	K10	154.634		
PU Activate Command	5	K3890	156.407				

*Time from simulated liftoff (T_0)
**Not assigned to DER for S-IVB-208

TABLE 5-1 (Sheet 5 of 7)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)		PCM/FM DIGITAL TABULATION (CAT 45)	
		MN	TIME*	MN	TIME*	MN	TIME*
PU Activate		K507	156.412				
Ullage Rocket Jettison Charge On Command	55	K3890	174.484				
EBW Charge 1						M38	175.0
EBW Charge 2						M39	175.0
Ullage Rocket Jettison Fire On Command	57	K3890	177.593				
Ullage Jettison Charge Command Reset	88	K3890	177.689				
EBW Fire 1				K149	177.684	M38	178.0
EBW Fire 2				K150	177.684	M39	178.0
Ullage Jettison Fire Command Reset	73	K3890	177.778				
Range Safety Off Enable On Command	85	K3890	**				
Auxiliary Hydraulic Pump Off Command	29	K3890	335.923				
Auxiliary Hydraulic Pump Off		K621	335.927				
Auxiliary Hydraulic Pump On Command	28	K3890	382.718				
Auxiliary Hydraulic Pump On		K621	382.721				
First Burn Relay Off Command	69	K3890	450.494				
First Burn Relay Off		K523	450.501				
Point Level Sensor On Command	97	K3890	568.873				
Non-Programmed Engine Cutoff		(If K400 Required)	816.879				

*Time from simulated liftoff (T_0)

**Not assigned to DER for S-IVB-208

TABLE 5-1 (Sheet 6 of 7)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)		PCM/FM DIGITAL TABULATION (CAT 45)	
		MN	TIME*	MN	TIME*	MN	TIME*
Engine Cutoff Lock-in Indication (ECC)		K539	576.873				
Ignition Phase Control Solenoid De-energized		K535	576.875	K6	-		
Mainstage Control Solenoid De-energized		K538	576.875	K5	-		
Engine Cutoff On Command	12	K3890	576.918				
Engine Cutoff Command On		K140	**	K140			
Main Oxidizer Valve Open (Dropout)		K120	576.968	K120	-		
Gas Generator Valve Open (Dropout)		K117	576.918	K117	-		
Main Fuel Valve Open (Dropout)		K118	577.006	K118	-		
Engine Pump Purge Control Valve Open Command	24	K3890	577.023				
Gas Generator Valve Closed		K631	576.951	K116	-		
Mainstage Pressure Switch B Depress		K573	577.057	K159	-		
Mainstage Pressure Switch A Depress		K572	577.057	K158	-		
Main Oxidizer Valve Closed		K633	577.077	K121	-		
Main Fuel Valve Closed		K632	577.189	K119			
Fuel Prevalve Open (Dropout)		K540	578.475	K111	578.556		
Oxidizer Prevalve Open (Dropout)		K541	578.475	K109	578.556		

*Time from simulated liftoff (T_0)

**Not assigned to DER for S-IVB-208

TABLE 5-1 (Sheet 7 of 7)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)		PCM/FM DIGITAL TABULATION (CAT 45)	
		MN	TIME*	MN	TIME*	MN	TIME*
Fuel Prevalve Closed		K549	578.475	K112	578.806		
Oxidizer Prevalve Closed		K550	578.937	K110	578.973		
Helium Control Solenoid De-energized		K531	577.863	K7	-		
Coast Period On Command	79	K3890	578.092				
Engine Start Off Command	27	K3890	578.446				
LH2 Chilldown Pump Off Command	59	K3890	578.678				
LOX Chilldown Pump Off Command	23	K3890	578.589				
PU Activate Off Command	6	K3890	580.061				
PU Activate Off		K507	580.064				
PU Inverter and DC Power Off Command	8	K3890	**				
Point Level Sensors Disarm Command	98	K3890	580.300 ***				
Ullage Jettison Charge Command Reset	88	K3890	581.700 ***				
First Burn Relay Off Command	69	K3890	581.800 ***				
Ullage Jettison Fire Command Reset	73	K3890	581.900 ***				

*Time from simulated liftoff (T_0)
**DER failure
***Time obtained from GSE oscillograph

6. ENGINE SYSTEM

The S-IVB-208 acceptance firing was performed with Rocketdyne engine S/N 2062 (figure 6-1) mounted on the stage. The engine performed satisfactorily throughout mainstage operation.

6.1 Engine Chilldown and Conditioning

6.1.1 Turbopump Chilldown

Chilldown of the engine LOX and LH2 turbopumps was adequate to provide the conditions required for proper engine start. An analysis of the chilldown operations is presented in paragraphs 7.4 and 8.2.

6.1.2 Thrust Chamber Chilldown

The thrust chamber skin temperature (figure 6-2) was 230 deg R at engine start command, well within the engine start requirement of 260 $\pm$50 deg R (table 6-1), and the LH2 pump demonstrated satisfactory start transient buildup characteristics (figure 6-3). Further information on the chilldown operation and ground support equipment supply system is presented in section 4.

6.1.3 Engine Start Sphere Chilldown and Loading

Chilldown and loading of the engine GH2 start sphere met the requirements for engine start (1,325 $\pm$75 psia and 290 $\pm$30 deg R). Start sphere performance is graphically presented in figure 6-4. The GH2 supply system performance during start sphere chilldown and loading is described in section 4. The sphere warmup rate from sphere pressurization to blowdown was 1.64 deg R/min. Significant data comparing three stages are presented in table 6-2. Repressurization of the start sphere was satisfactorily accomplished during engine operation.

6.1.4 Engine Control Sphere Chilldown and Loading

Engine control sphere conditioning was adequate (figure 6-4), and all objectives were satisfactorily accomplished. The engine start requirements of 290 $\pm$30 deg R and 2,800 to 3,450 psia were met. Significant control sphere performance data comparing three stages are presented in table 6-3.

6.2 J-2 Engine Performance Analysis Methods and Instrumentation

Engine performance for the acceptance firing was calculated by the use of computer programs G105-3 and F823-1. A description of the operation and a comparison of the results of each program is presented in table 6-4.

Several biases were necessary to correct for known data discrepancies. The thrust chamber pressure was biased -15 psia, as recommended by Rocketdyne, because of a transducer purge. From an analysis of the raw test pip-count data, the engine flowmeter data were biased +9.74 gpm for LOX and +25.6 gpm for LH2.

In the F823-1 program, coefficients relating gas generator mixture ratio to LOX turbine inlet temperature were substituted for those relating the gas generator mixture ratio to the LH2 turbine inlet temperature which are normally used. The substitution was made because the LH2 turbine inlet temperature transducer malfunctioned. The percent of samples included in 3-sigma deviation using GG mixture ratio as a function of LH2 turbine inlet temperature is 99.998 percent; whereas, the percent of samples included in 3-sigma deviation GG mixture ratio as a function of LOX turbine inlet temperature is 99.381 percent.

6.3 J-2 Engine Performance

The engine performed in a manner that was predicted and sufficient to allow the S-IVB stage to complete its mission. Plots of selected data used as inputs to the computer programs listed in table 6-4 are presented in figures 6-5 through 6-10. The engine propellant inlet conditions are presented in sections 7 and 8. The performance levels compare well with those established during the Rocketdyne acceptance test series, and all test objectives were accomplished. One anomaly was noted at approximately ESC +342 sec when a performance shift occurred. This shift was caused by a sudden decrease in flow through the propellant utilization (PU) valve while the valve was being driven from the closed to the open position. At the time of the shift, the valve was at approximately +2 deg.

The engine performance was reconstructed from engine start command to cutoff by the computer programs described in table 6-4. Necessary modifications to the data and computer programs were made as indicated in paragraph 6.2. The average performance values from each program are shown in table 6-5. The performance profiles of the programs, as well as the composite profiles, are shown in figures 6-11 and 6-12. The composite values consititute the final engine performance values as presented in table 6-5.

Flow integral mass analysis indicates that 190,894 lbm of LOX and 36,089 lbm of LH2 were consumed (see section 10) between engine start and engine cutoff commands. This preliminary estimate of propellant consumption will be refined and the final evaluation will be presented in the flow integral cryogenic calibration report on the S-IVB-208 propellant utilization system.

The analysis also indicates that the overall stage average thrust from 90 percent thrust to engine cutoff was 228,242 lbf. The average mixture ratio and specific impulse were 5.327 and 427.59 sec, respectively, for the same time period. The total impulse generated during this time was 96.66 X 10^6 lbf-sec. Extrapolating the propellant residuals as indicated by the point level sensors (1,558 lbm of LOX, 962 lbm of LH2) indicates that a fuel depletion cutoff would have occurred at ECC +2.55 sec. In that time, an additional 498,784 lbf-sec impulse would have been generated, thereby making the total stage potential impulse from engine start command to the end of the thrust decay 97.38 X 10^6 lbf-sec, as compared to the predicted value of 97.50 X 10^6 lbf-sec. The 0.123 percent deviation is within the accuracy of the prediction. The actual depletion time was 10.882 sec earlier than predicted. Of this deviation, 4.4 sec could be attributed to the extended operation with the PU valve closed. The remainder has been attributed to loading errors and the performance increase of the uprated engine.

6.3.1 Start Transient

The J-2 engine start transient was satisfactory. A summary of engine performance is presented in the following table:

Parameter	Acceptance Firing	Log Book
Time to 90 percent performance level (sec)	3.105	2.58*
Thrust rise time (sec)	1.955	2.10
Total impulse (lbf-sec)	171,169	183,317**
Maximum rate of thrust increase (lbf/10 ms)	7,327	40,000***

*Referenced to start tank discharge valve. Acceptance firing start tank discharge control solenoid energized at ESC +637 ms.

**Based on stabilized thrust at null PU and standard altitude conditions. (Test No. 313-030).

***Maximum allowable

The deviation in total impulse from the log book is due to the faster thrust rise time (time from first indication of thrust to the 90 percent performance level) during the acceptance firing. Figure 6-13 shows the thrust chamber pressure during start transient and the thrust buildup to the 90 percent performance level for the acceptance firing as determined by computer program F839. Thrust buildup to the 90 percent performance level (thrust chamber pressure = 627 psia) was within the maximum and minimum thrust bands. As expected, there was no thrust overshoot during the start transient.

6.3.2 Steady-State Performance

Satisfactory performance of the J-2 engine was demonstrated throughout the steady-state protion of the engine burn. There was indication of a performance shift shortly after PU valve cutback, as can be seen at ESC +342 sec in the performance profiles of figure 6-11. The performance deviations resulting from the shift are given in table 6-5.

This shift was noted in all major engine instrumentation and was reflected in the evaluation programs, F823-1 and G105-3, which are based on internal engine measurements. The PU valve position did not indicate a shift, although a simultaneous increase in oxidizer pump discharge pressure and decrease in PU valve discharge pressure occurred. This phenomena has been observed in previous firings and has been attributed to the hydraulic resistance of the PU valve.

Table 6-5 compares the overall average performance values for steady-state operation with the predicted values. The high performance values are the result of the uprated (230,000 lbf thrust) J-2 engine on S-IVB-208. This table also gives the performance deviations caused by the shift at ESC +344 sec. The deviation between PU valve predicted cutback time (ESC +280 sec) and actual cutback time (ESC +303 sec) is discussed in section 10.

The engine thrust variations during the acceptance firing are presented in table 6-6. Expanded thrust plots during the periods discussed are presented in figures 6-14 and 6-15. Comparison is made to acceptance firing history predictions and to Marshall Space Flight Center (MSFC) suggested allowable limits for flight. These limits do not apply to acceptance firing performance and are presented for reference purposes only. Thrust variations during flight will be modified by flight effects on stage operation. Thrust variations were noted during the following four phases of engine operation:

a. Hardover or maximum engine mixture ratio operation (EMR = 5.5/1.0)

b. Transient phase (PU valve cutback +50 sec to ECC -70 sec)

c. Final 40 sec of burn

d. Final 70 sec of burn

The thrust variations during the hardover operation were within the suggested allowable limits for normal operation. Normal operating thrust variations during this time period are caused by engine stabilization and stage perturbations including the effects of variations in propellant supply conditions. The time period from PU valve cutback +50 sec to

ECC -70 sec was nonexistent during this firing because of the late PU valve cutback.

The time period from ECC -70 sec to engine cutoff command includes the transient performance results. The transient performance during this period was caused by the late PU valve cutback. Because of the late cutback, the MSFC suggested allowable limits on thrust variations were exceeded in all categories. Acceptance firing data will aid in the flight calibration of the PU system in order to eliminate the deviations in the PU valve cutback.

The time period from ECC -40 sec to engine cutoff command is reported in addition to the normal periods discussed in an effort to show a more stable period of engine operation. The thrust variations during this period were influenced primarily by movements of the PU valve and, to a secondary degree, by variations in stage performance. The thrust variations were within the suggested flight limits for the maximum rate of change and for the deviation from predicted mean slope. Deviations in the other categories are attributed to the transient operation caused by the late PU valve cutback.

6.3.3 Cutoff Transient

The time lapse between engine cutoff as received at the J-2 engine, and thrust decrease to 11,250 lbf was not within the maximum allowable time (800 ms) for the acceptance firing as shown in the following table.

Parameter	Acceptance Firing	Log Book
Thrust decrease to 11,250 lbf (ms)	875	301**
Total impulse (lbf-sec)	47,233*	34,261**

*PU valve at -4.8 deg

**PU valve at null position, standard altitude conditions, average of tests 313-028, 313-029, 313-030, and 313-031

The performance values presented are not in satisfactory agreement with the log book of the Rocketdyne J-2 Manual No. R-3825-1 (0.345 ±0.030 sec and 35,000 $\pm$1,650 lbf-sec, based on a main LOX valve temperature of 0 deg F, PU valve in the null position, and defined from cutoff signal to 5 percent of rated thrust). Stage performance during flight should not be adversely affected by these conditions.

The deviation in cutoff impulse to 11,250 lbf from Rocketdyne nominal values (which are based on thrust load cell data) are probably caused by a time lag in the chamber pressure measurement from which computer program F839 calculates cutoff impulse.

The time lag is under investigation by the engine manufacturer. The actual cutoff impulse was probably less than that calculated by program F839. Figure 6-16 presents the thrust chamber pressure data for the cutoff transient and the cutoff transient thrust. Figure 6-17 presents accumulated cutoff impulse from engine cutoff to 11,250 lbf thrust for the acceptance firing.

6.4 Engine Sequencing

The engine sequencing was satisfactory throughout the acceptance firing and compatible with the engine logic and the acceptance firing test plan. Figure 6-18 presents the engine start sequence for the acceptance firing; table 6-7 presents the time of significant events during the firing and compares them with the nominal values. The noted time discrepancies are explained by the effect of the propellants present in the engine.

An orifice was installed in the gas generator valve control line to delay the opening of the valve by approximately 65 ms, thereby eliminating the high line pressure effects on the main LOX valve. Satisfactory results were obtained. Because of the LOX sampling rate (12 sps) and the lack of FM data, all sequence of events data are only accurate to $\pm$80 ms.

6.5 Component Operation

All components on J-2 engine S/N 2062 performed satisfactorily during the S-IVB-208 acceptance firing. The main LOX valve opened satisfactorily. However there was evidence (figure 6-18) of a slight retardation of the second stage opening due to the buildup of the LOX pump discharge pressure.

The retardation did not affect the start transient. Steady state performance of the gas generator is shown on figure 6-19. The main LOX valve opening time data were as follows:

Parameter	Specification	Actual
First stage travel (ms)	50 ±25	67
Plateau (ms)	510 ±70	520
Second stage travel (ms)	1,825 ±75	1,923

The engine driven hydraulic pump performed satisfactorily during the acceptance firing. The gimbal program was conducted between approximately ESC +44 and ESC +101 sec. Calculations made during the gimbal program showed the following/hydraulic pump performance:

Time From ESC (sec)	Horsepower Required (hp)
60	4.27
80	9.22
100	8.35

This is point function data only and no extrapolations are to be made between the time points given. For times prior to 44 sec and after 101 sec, the required hp was 0.92. On subsequent acceptance firings the gimbal program will be initiated at ESC +70 sec, thereby making horsepower requirements constant at key evaluation times. No tag evaluations will be made during the gimbal program.

6.6 Engine Vibration

Four vibration measurements were monitored on the engine which included one at the LOX turbopump, one at the LH2 turbopump, and two on the combustion chamber dome. The LOX turbopump data were invalid as explained in section 11. The data from the three valid measurements are shown in figure 6-20. The vibration levels at these locations were comparable to those measured on past acceptance firings.

TABLE 6-1
THRUST CHAMBER CHILLDOWN

PARAMETER	S-IVB-208	S-IVB-207	S-IVB-206
Engine start requirement (deg R)	260 $\pm$50	260 $\pm$50	260 $\pm$50
Thrust chamber childown initiated (sec)	T_0 -1201	T_0 -1200	T_0 -1201
Thrust chamber childown terminated (sec)	T_0 +127	T_0 +127	T_0 +126
Thrust chamber temperature (C0199) at end of childown (deg R)	227	240	232
Thrust chamber temperature at engine start (deg R)	230	250	235

TABLE 6-2
ENGINE START SPHERE PERFORMANCE

PARAMETER	TEMPERATURE (deg R)			PRESSURE (psia)			MASS (lbm)		
	208	207	206	208	207	206	208	207	206
Engine start requirement		290 $\pm$30			1,325 $\pm$75				
Engine Start Command	258	292	252	1,342	1,312	1,346	3.83	3.32	3.95
After start sphere blowdown	168	200	156	160	169	184	0.72	0.66	0.83
Engine cutoff	225	205	207	1,362	1,300	1,463	4.48	3.85	5.24
Total GH2 usage during start							3.11	2.66	3.12

TABLE 6-3
ENGINE CONTROL SPHERE PERFORMANCE

PARAMETER	TEMPERATURE (deg R)			PRESSURE (psia)			MASS (lbm)		
	208	207	206	208	207	206	208	207	206
Engine start requirement		290 ± 30			2,800 to 3,450				
Engine Start Command	270	296	261	3,144	3,264	3,150	2.08	1.98	2.15
Engine cutoff	229	252	217	2,139	2,187	2,057	1.73	1.61	1.81
Total helium usage							0.35	0.37	0.42

TABLE 6-4
COMPARISON OF COMPUTER PROGRAM RESULTS

PROGRAM	INPUT	METHOD	RESULTS
G105 Mode 3	LOX and LH2 flowmeters, pump discharge pressures and temperatures, chamber pressures, chamber thrust area	Flowrates are computed from flowmeter data and propellant densities. The C_F is determined from equation $C_F = f\ (P_c,\ MR)$ and thrust is calculated from equation $F = C_F\ A_t\ P_c$.	$F = 228{,}239$ lbf $\dot{W}_T = 532.81$ lbm/sec $I_{sp} = 428.47$ sec $MR = 5.31$
F823 Mod 1	Thrust chamber pressure, gas generator pressure, fuel injection temperature, fuel pump discharge temperature, fuel turbine inlet temperature	Total flows of the thrust chamber and gas generator are calculated as a function of respective chamber pressures. Mixture ratio of the chamber is calculated as a function of temperature rise of the fuel in the cooling jacket, and misture ratio of the GG is calculated as a function of turbine inlet temperature. Thrust is calculated from the equation $F = C_F\ A_t\ P_c$.	$F = 228{,}306$ lbf $\dot{W}_T = 535.23$ lbm/sec $I_{sp} = 426.71$ sec $MR = 5.34$
F839	Thrust chamber pressure, chamber throat area	The C_F is computed from equation $C_F = f\,(P_c)$ and thrust is computed from equation $F = C_F\ A_t\ P_c$. The impulse is determined from integrated thrust.	Refer to paragraphs 6.3.1 and 6.3.3

TABLE 6-5
ENGINE PERFORMANCE

PARAMETER	CLOSED PU VALVE OPERATION			REFERENCE MIXTURE RATIO			OVERALL PERFORMANCE			PERFORM SHIFT	
	ACTUAL	PRE-DICTED	% DEV	ACTUAL	PRE-DICTED	% DEV	ACTUAL	PRE-DICTED	% DEV	SHIFT	% DEV
Thrust (lbf)	236,360	234,750	-0.70	198,313	196,477	-0.90	228,273	223,984	-1.9	1,890	0.95
Total flowrate (lbm/sec)	554.12	553.49	-0.10	459.40	454.94	-1.0	534.02	525.89	-1.5	4.90	1.07
LOX flowrate (lbm/sec)	468.59	469.11	0.10	379.98	375.92	-1.1	449.72	443.05	-1.5	4.60	1.21
LH2 flowrate (lbm/sec)	85.53	84.38	-1.4	79.40	79.02	-0.50	84.31	82.84	-1.8	0.30	0.38
Engine mix-ture ratio	5.479	5.560	1.5	4.786	4.757	-0.60	5.327	5.339	0.20	0.04	0.84
Specific impulse (sec)	426.55	424.12	-0.60	431.70	431.87	0.04	427.59	426.17	-0.30	-0.42	-0.10

TABLE 6-6
ENGINE THRUST VARIATIONS

TIME PERIOD		HARDOVER	TRANSIENT FROM VALVE CUTBACK +50 SEC TO ECC -70 SEC	FINAL 40 SEC OF BURN	FINAL 70 SEC OF BURN
Mean slope (lbf/sec)	Allowable*	-	-	±44	
	Actual	-	-	+70	-60
	Predicted	-	-	22	-9
Maximum rate (lbf/sec)	Allowable*	±500	±500	±354	
	Actual	±270	N/A	-300	-440
	Predicted	±180	±200	100	100
Maximum (zero-to-peak) amplitude (lbf)	Allowable*	±2500	±7500	±1000	
	Actual	±750	N/A	±1300	±2200
	Predicted	±500	±1000	±250	±650
Maximum deviation from predicted amplitude of mean slope (lbf)	Allowable*	±4000	±3000	±3000	
	Actual	+2300	N/A	2900 at ECC -40	4800 at ECC -70
Deviation from predicted rate of mean slope (lbf/sec)	Allowable*	-	-	28	
	Actual	-	-	48	51

* MSFC flight limits

N/A - Not applicable

TABLE 6-7 (Sheet 1 of 5)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE (ENGINE DRY)	ACTUAL TIME (ms)	
MEAS. NO.	EVENT AND COMMENT	MEAS. NO.	EVENT AND COMMENT		FROM ESC	FROM SPEC. REF.
K0021	*Engine Start Command P/U			0	0	0
		K0007	Helium Control Solenoid Enrg P/U	Within 10 ms of K0021	2	2
		K0010	Thrust Chamber Spark on P/U	Within 10 ms of K0021	3	3
		K0011	Gas Generator Spark on P/U	Within 10 ms of K0021	3	3
		K0006	Ignition Phase Control Solenoid Enrg P/U	Within 20 ms of K0021	3	3
		K0012	Engine Ready D/O	Within 20 ms of K0006	6	3
		K0126	LOX Bleed Valve Closed P/U	Within 120 ms of K0007	68	66
		K0127	LH2 Bleed Valve Closed P/U	Within 120 ms of K0007	60	58
		K0020	ASI LOX Valve Open P/U	Within 20 ms of K0006	40	37
		K0119	Main Fuel Valve Closed D/O	60 $\pm$30 ms from K0006	48	45
		K0118	Main Fuel Valve Open P/U	80 $\pm$50 ms from K0119	107	59
K0008	**Ignition Detected			Within 250 ms of K0021 P/U	138	138
K0021	***Engine Start Command D/O			Approx 500 ms from K0021 P/U	578	578

*Engine ready and stage separation signals (or simulation) are required before this command will be executed. This command also actuates a 640 $\pm$30 ms timer which controls energizing of the start tank discharge solenoid N010 (K0096).

**This signal must be received within 1,110 $\pm$60 ms of K0021 P/U or cutoff will be initiated.

***This signal drops out after a time sufficient to lock in the engine electrical.

TABLE 6-7 (Sheet 2 of 5)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE (ENGINE DRY)	ACTUAL TIME (ms)	
MEAS. NO.	EVENT AND COMMENT	MEAS. NO.	EVENT AND COMMENT		FROM ESC	FROM SPEC. REF.
K0096	*Start Tank Disc Control Solenoid Enrg			640 ±30 ms from K0021	637	637
		K0123	Start Tank Disc Valve Closed D/O	100 ±20 ms from K0096	780	143
		K0122	Start Tank Disc Valve Open P/U	105 ±20 ms from K0123	880	100
K0005	Mainstage Control Solenoid Enrg			450 ±30 ms from K0096	1082	445
		K0096	Start Tank Disc Control Solenoid Enrg D/O	450 ±30 ms from K0096	1082	445
		K0121	Main LOX Valve Closed D/O	50 ±20 ms from K0005	1188	106
		K0116	Gas Generator Valve Closed D/O	75 ±25 ms from K0005	1170	88
		K0122	Start Tank Disc Valve Open D/O	95 ±20 ms from K0096	1185	103
		K0117	Gas Generator Valve Open P/U	190 ±15 ms from K0116	1304	134
		K0124	LOX Turbine Bypass Valve Open D/O	Within 100 ms of K0005	1270	188
			LOX Turbine Bypass Valve 80% Closed	400 $^{+150}_{-50}$ ms from K0122	1500	315

*An indication of fuel injection temperature of -150 ±40 deg F (or simulation) is required before this command will be executed. This command also actuates a 450 ±30 ms timer which controls the start of mainstage.

TABLE 6-7 (Sheet 3 of 5)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE (ENGINE DRY)	ACTUAL TIME (ms)	
MEAS. NO.	EVENT AND COMMENT	MEAS. NO.	EVENT AND COMMENT		FROM ESC	FROM SPEC. REF.
		K0123	Start Tank Disc Valve Closed P/U	250 $\pm$40 ms from K0122	1440	255
		K0125	*LOX Turbine Bypass Valve Closed P/U		1550	-
K0158	Mainstage Press. Switch #1 Depress. D/O				2527	-
K0159	Mainstage Press. Switch #2 Depress. D/O				2534	-
K0191	**Mainstage OK				2529	-
		K0120	Main LOX Valve Open P/U	2485 $\pm$170 ms from K0005	3640	2558
		K0010	Thrust Chamber Spark on D/O	3300 $\pm$200 ms from K0010 P/U	4364	4361
		K0011	Gas Generator Spark on D/O	3300 $\pm$200 ms from K0011 P/U	4450	4447
K0507 CSS-22	PU Activate Switch P/U				6142	-

*Within 5,000 ms of K0005 (Normally = 500 ms)

**One of these signals must be received within 4,410 $\pm$260 ms from K0021 P/U, or cutoff will be initiated. Signal occurs when LOX injection pressure is 500 $\pm$30 psig

TABLE 6-7 (Sheet 4 of 5)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE (ENGINE DRY)	ACTUAL TIME (ms)	
MEAS. NO.	EVENT AND COMMENT	MEAS. NO.	EVENT AND COMMENT		FROM ECC	FROM SPEC. REF.
K0013	Engine Cutoff PU (New time reference)			0	0	0
		K0005	Mainstage Control Solenoid Enrg D/O	Within 10 ms of K0140	2	-
		K0006	Ignition Phase Control Solenoid Enrg D/O	Within 10 ms of K0140	2	-
		K0020	ASI LOX Valve Open D/O		23	21
		K0120	Main Oxidizer Valve Open D/O	60 ±15 ms from K0005	95	93
		K0117	Gas Generator Valve Open D/O	75 $^{+25}_{-35}$ ms from K0006	33	31
		K0118	Main Fuel Valve Open D/O	90 ±25 ms from K0006	133	131
		K0121	Main Oxidizer Valve Closed P/U	120 ±15 ms from K0120	204	109
		K0116	Gas Generator Valve Closed P/U	Within 500 ms from K0006	78	76
		K0119	Main Fuel Valve Closed P/U	225 ±25 ms from K0118	316	183
K0158	*Mainstage Press. Switch A Depress. P/U			*	184	-
K0159	Mainstage Press. Switch B Depress. P/U			*	184	-
K0191	Mainstage OK D/O			*	187	-

*Signal drops out when pressure reaches 425 ±25 psig.

TABLE 6-7 (Sheet 5 of 5)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE (ENGINE DRY)	ACTUAL TIME (ms)	
MEAS. NO.	EVENT AND COMMENT	MEAS. NO.	EVENT AND COMMENT		FROM ECC	FROM SPEC. REF.
K0007	Helium Control Solenoid Enrg D/O			1,000 $\pm$110 ms from K0140	990	990
SS-22 K0507	PU Activate Switch D/O			N/A	3,191	-
		K0125	Oxidizer Turbine Bypass Valve Closed D/O		310	-
		K0124	Oxidizer Turbine Bypass Valve Open P/U	10,000 ms from K0005	814	814
K0126	LOX Bleed Valve Closed D/O			Within 30,000 ms from K0005	10,727	10,725
K0127	LH2 Bleed Valve Closed D/O			Within 30,000 ms from K0005	3,333	3,331

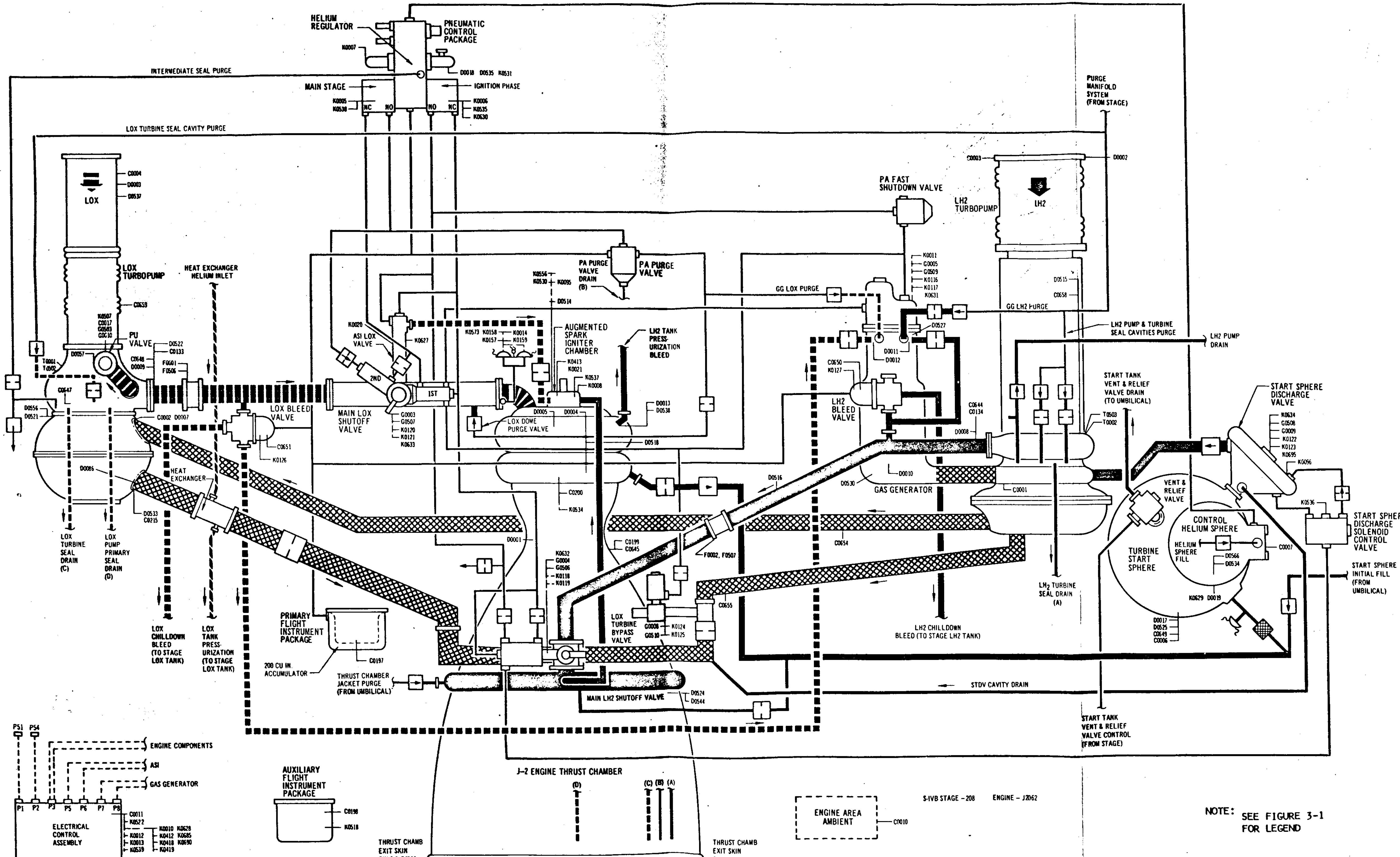


Figure 6-1. J-2 Engine System and Instrumentation

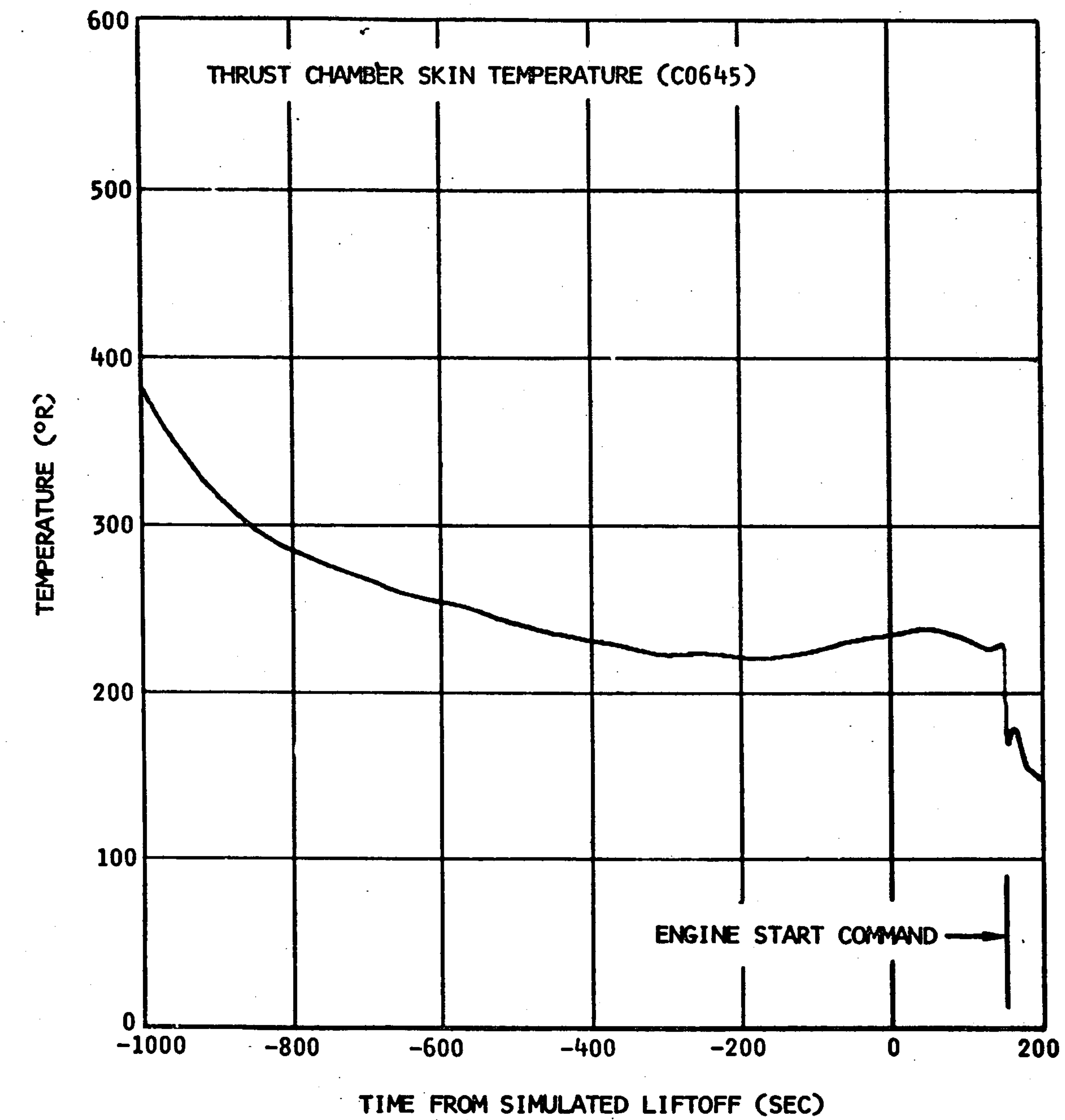


Figure 6-2. Thrust Chamber Chilldown

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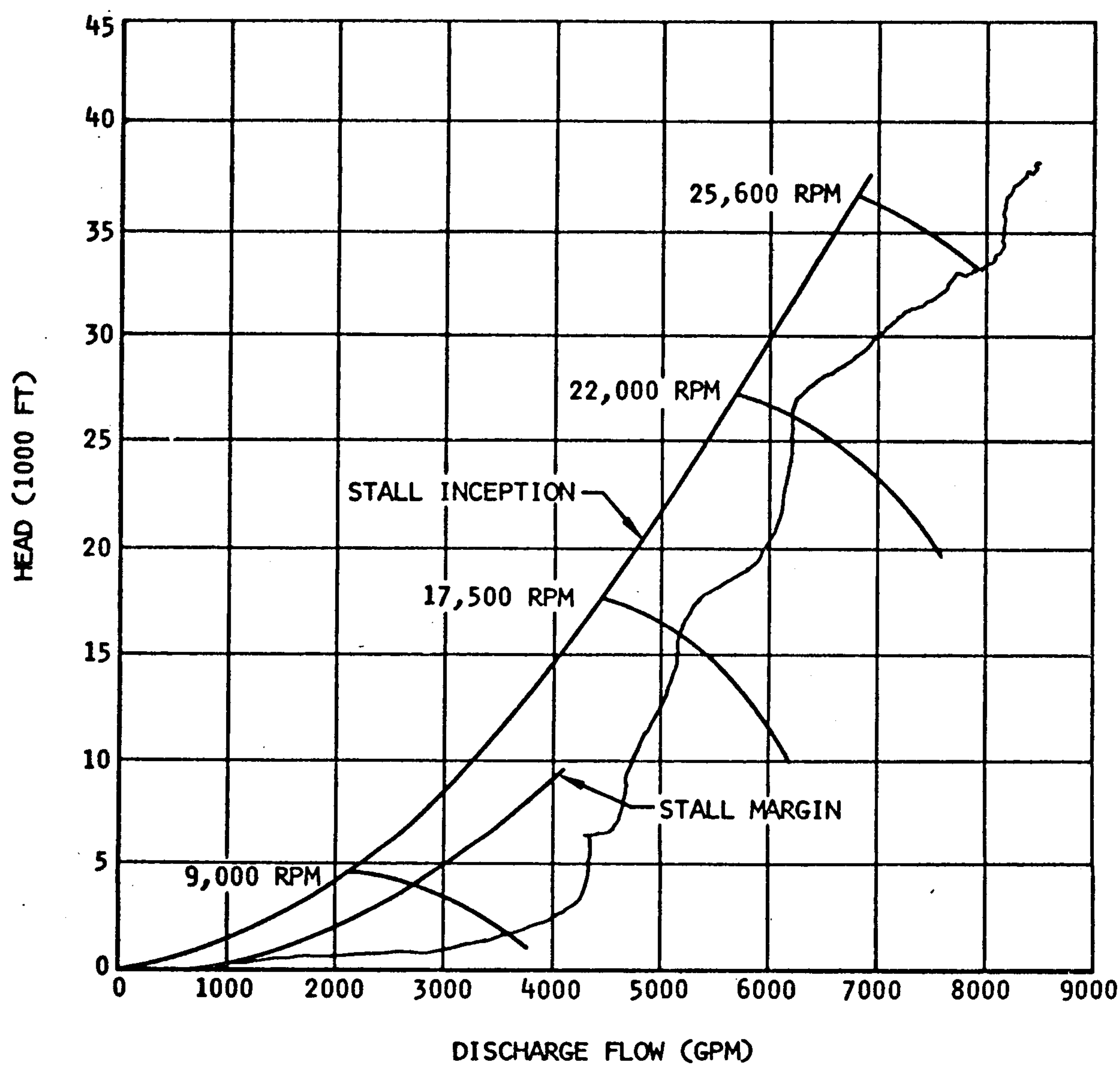

Figure 6-3. LH2 Pump Performance During Engine Start

27 March 1967

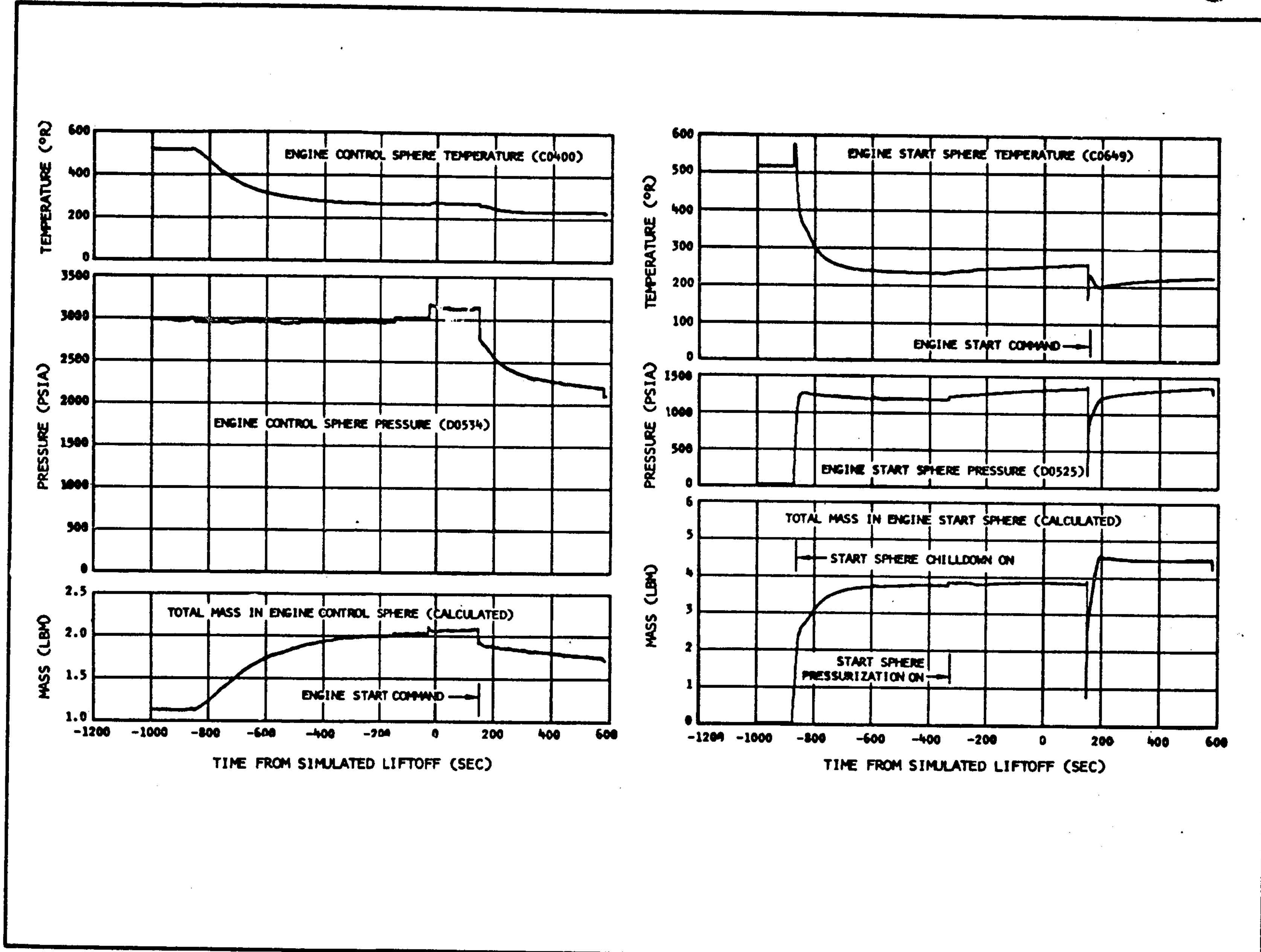

Figure 6-4. Engine Start and Control Sphere Performance

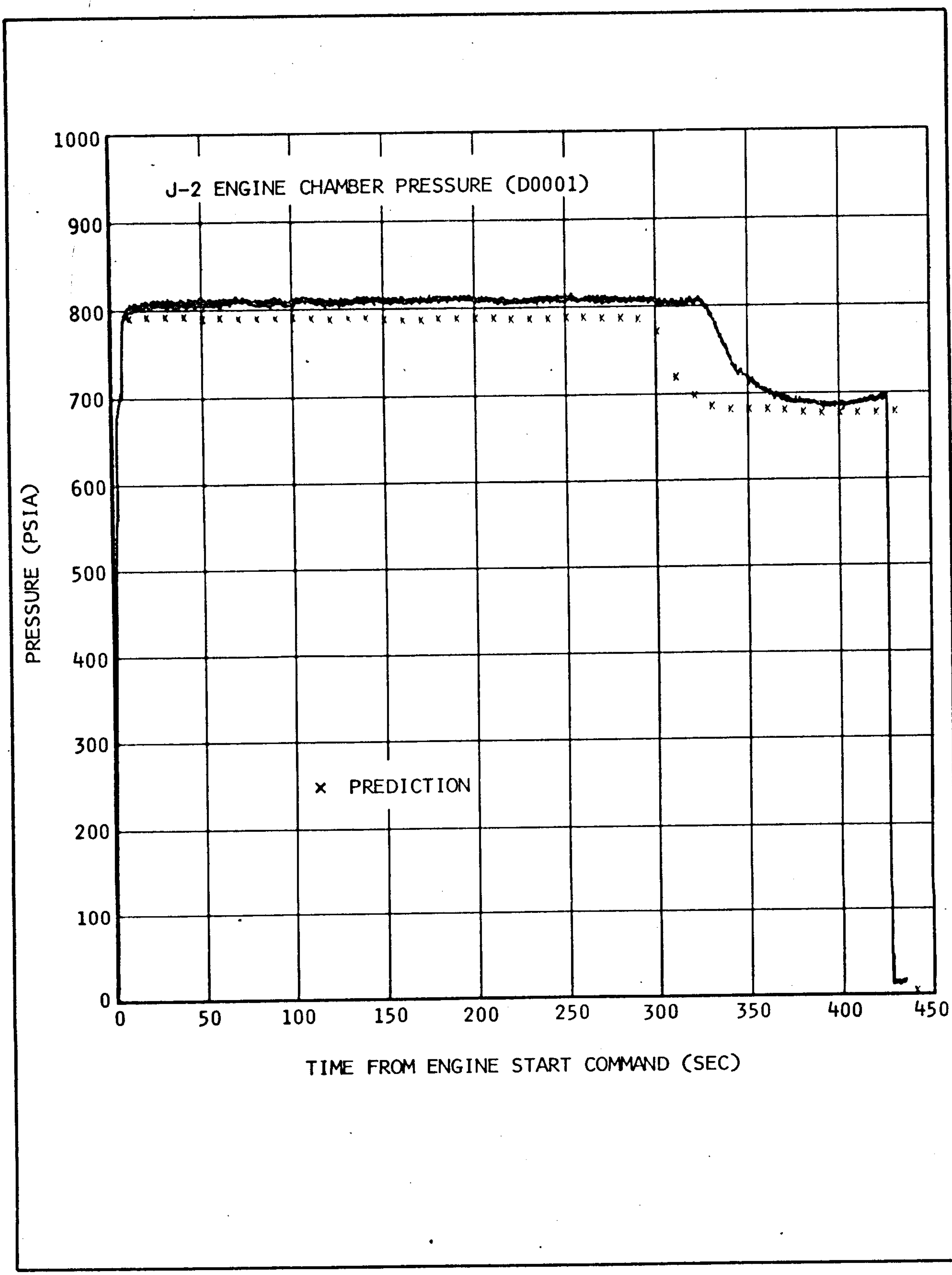

Figure 6-5. J-2 Engine Chamber Pressure

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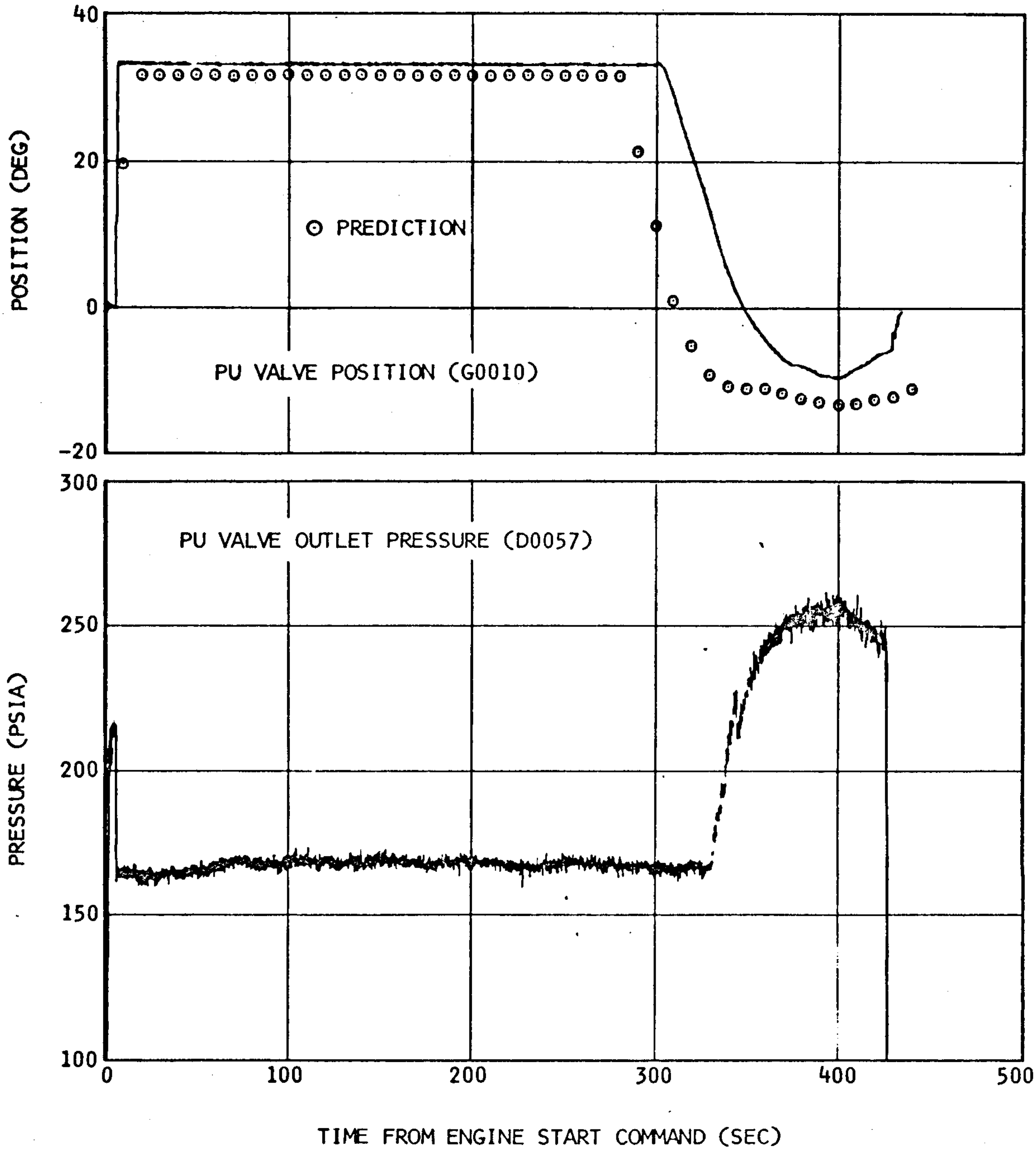

Figure 6-6. PU Valve Operation

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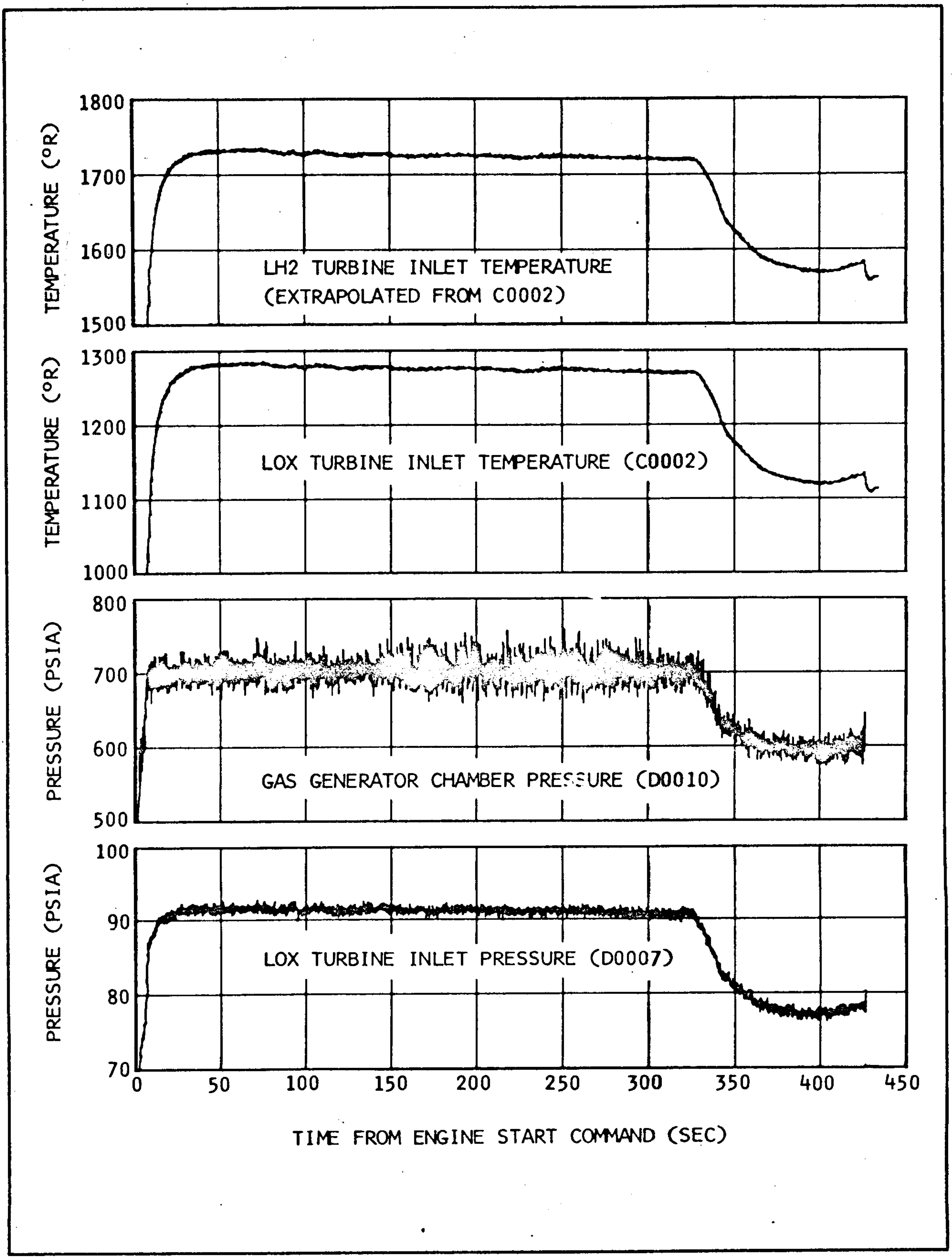

Figure 6-7. Turbine Inlet Operating Conditions

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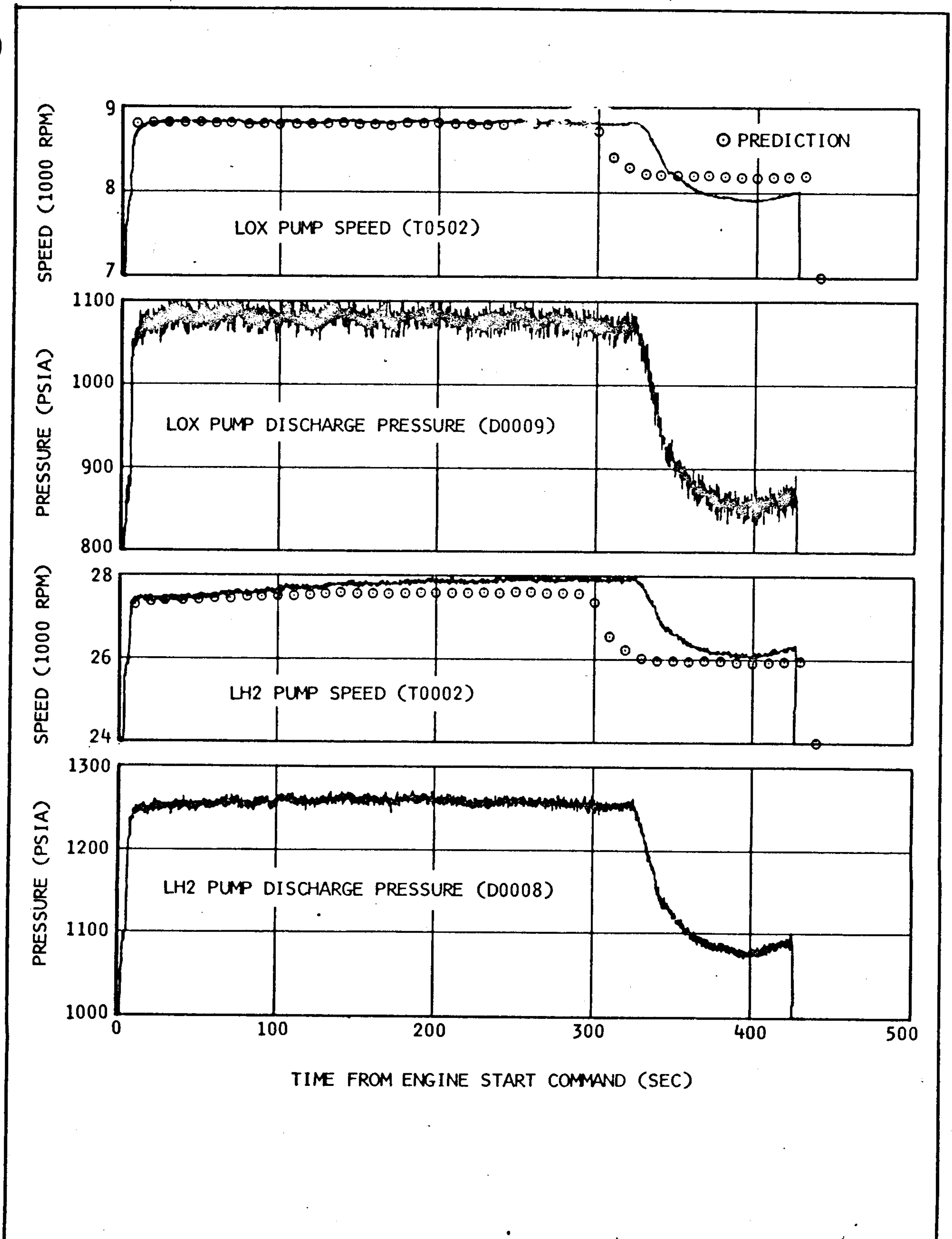

Figure 6-8. J-2 Engine Pump Operating Characteristics

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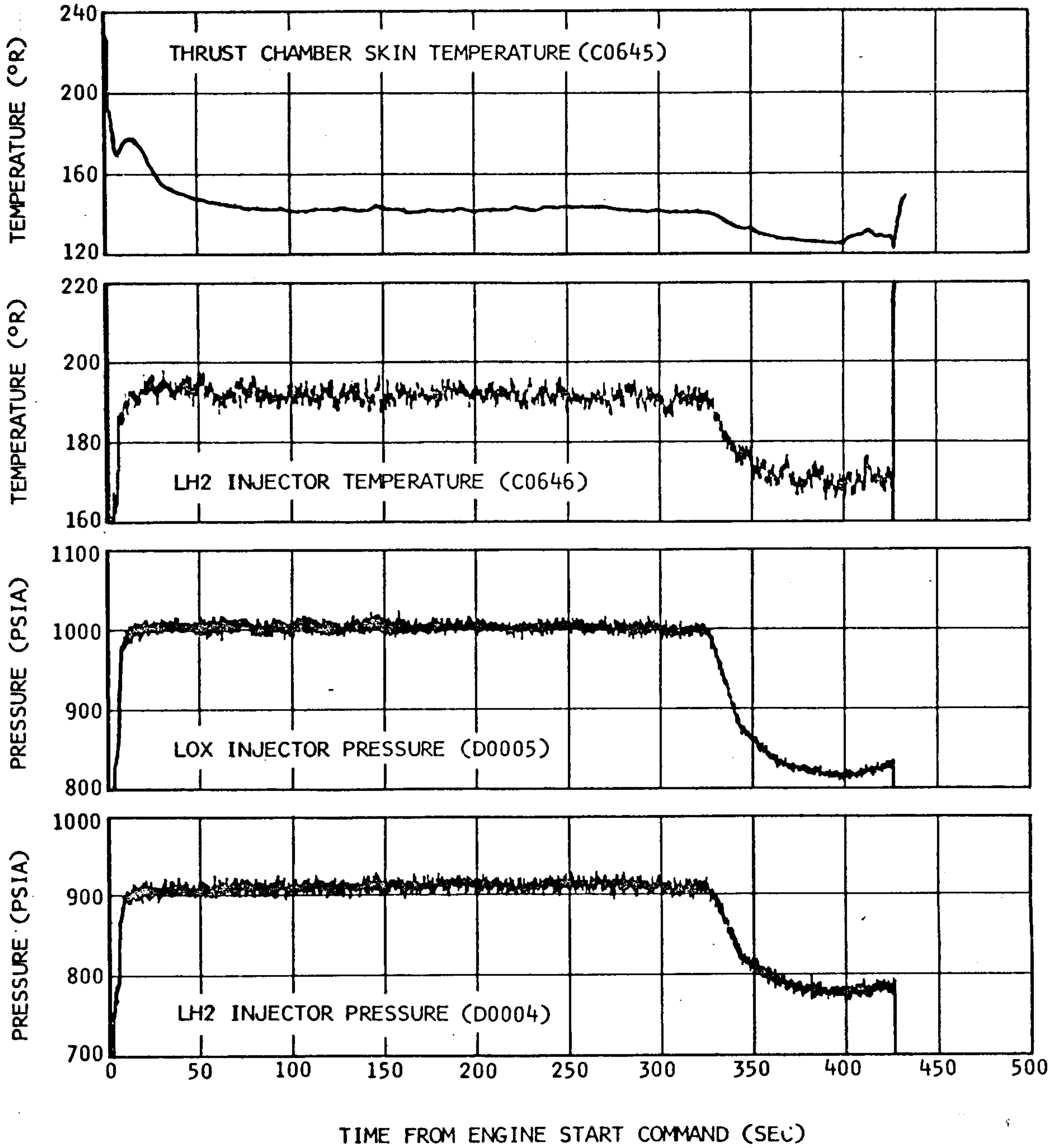

Figure 6-9. J-2 Engine Injector Supply Conditions

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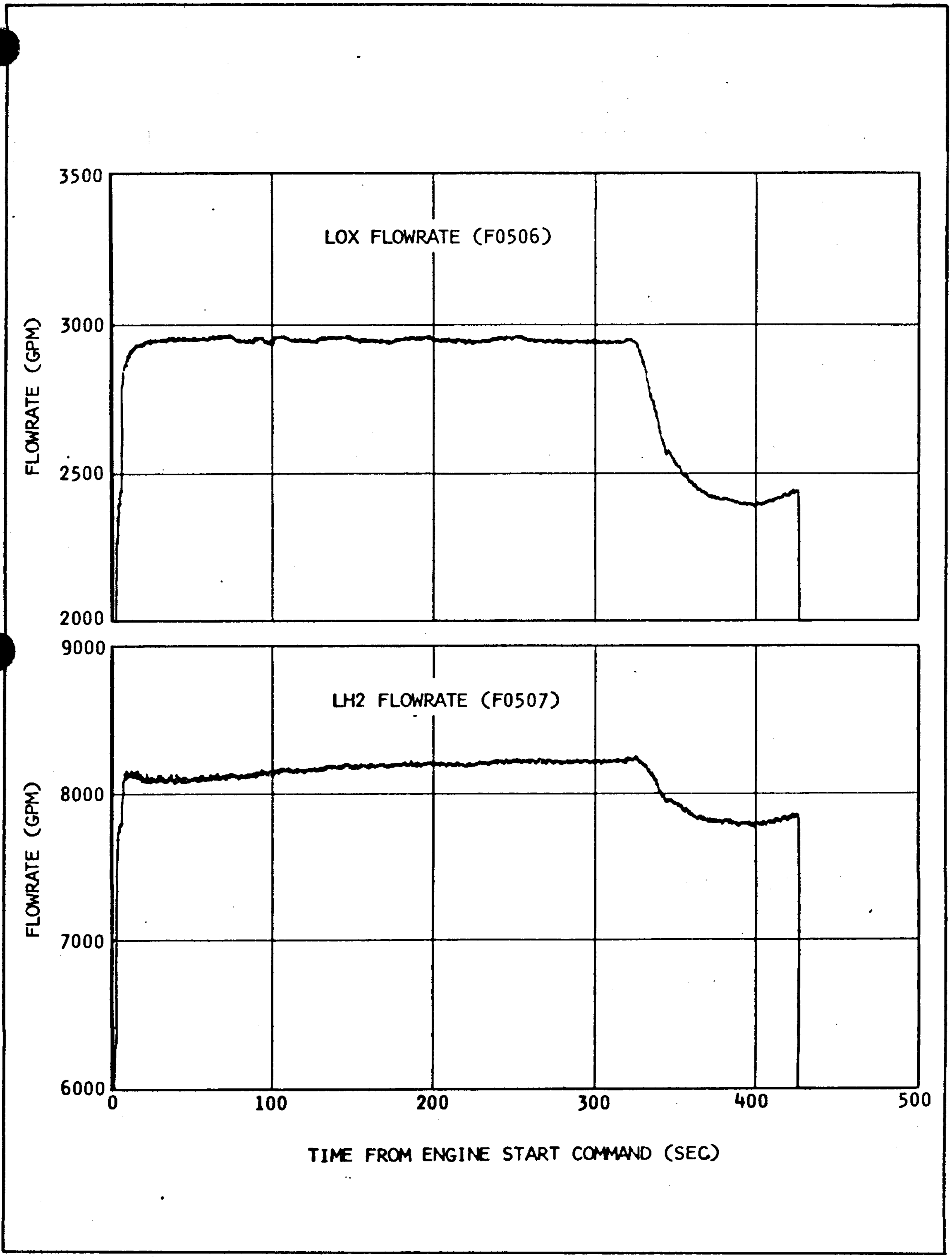

Figure 6-10. LOX and LH2 Flowrate

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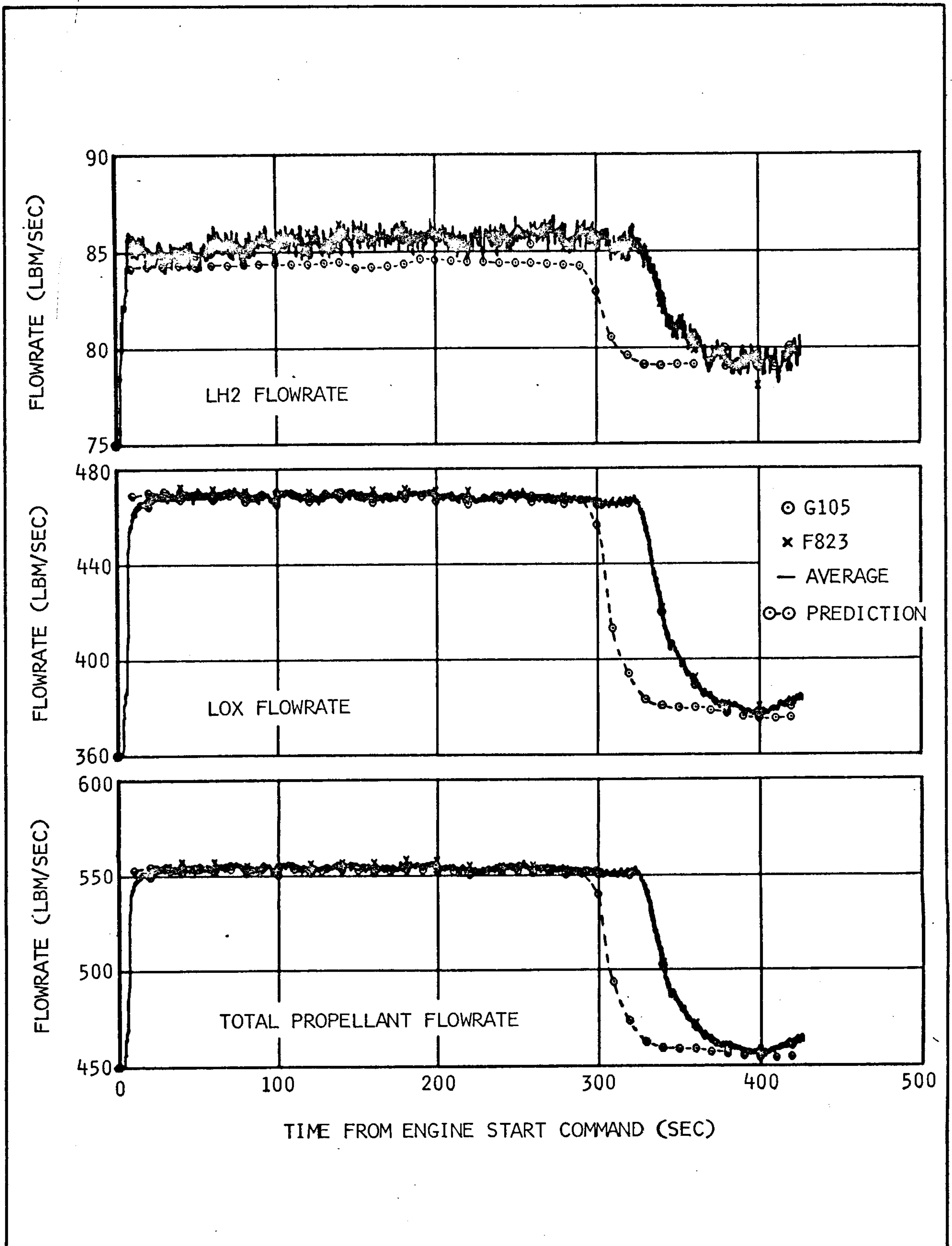

Figure 6-11. Engine Steady State Performance (Sheet 1 of 2)

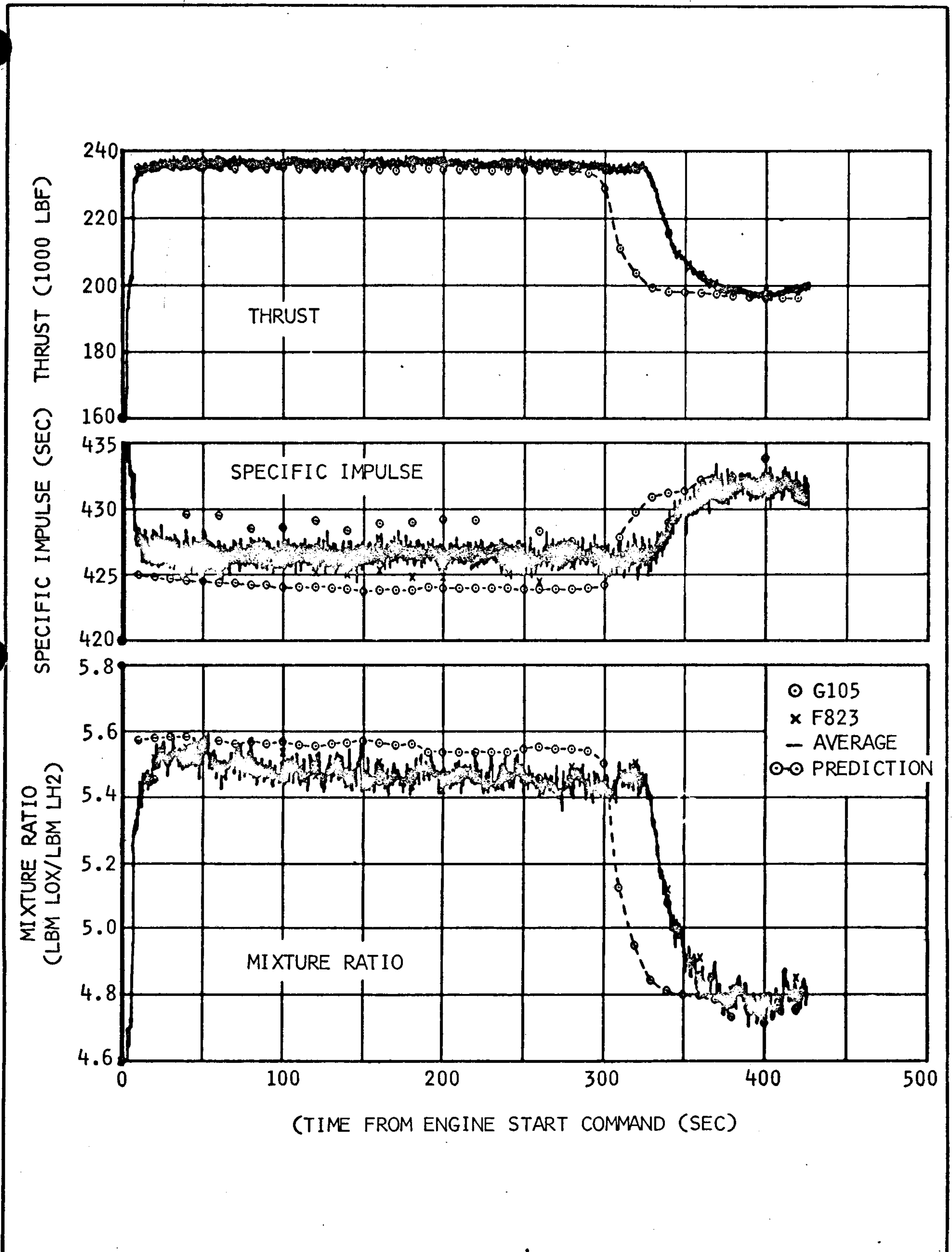

Figure 6-11. Engine Steady State Performance (Sheet 2 of 2)

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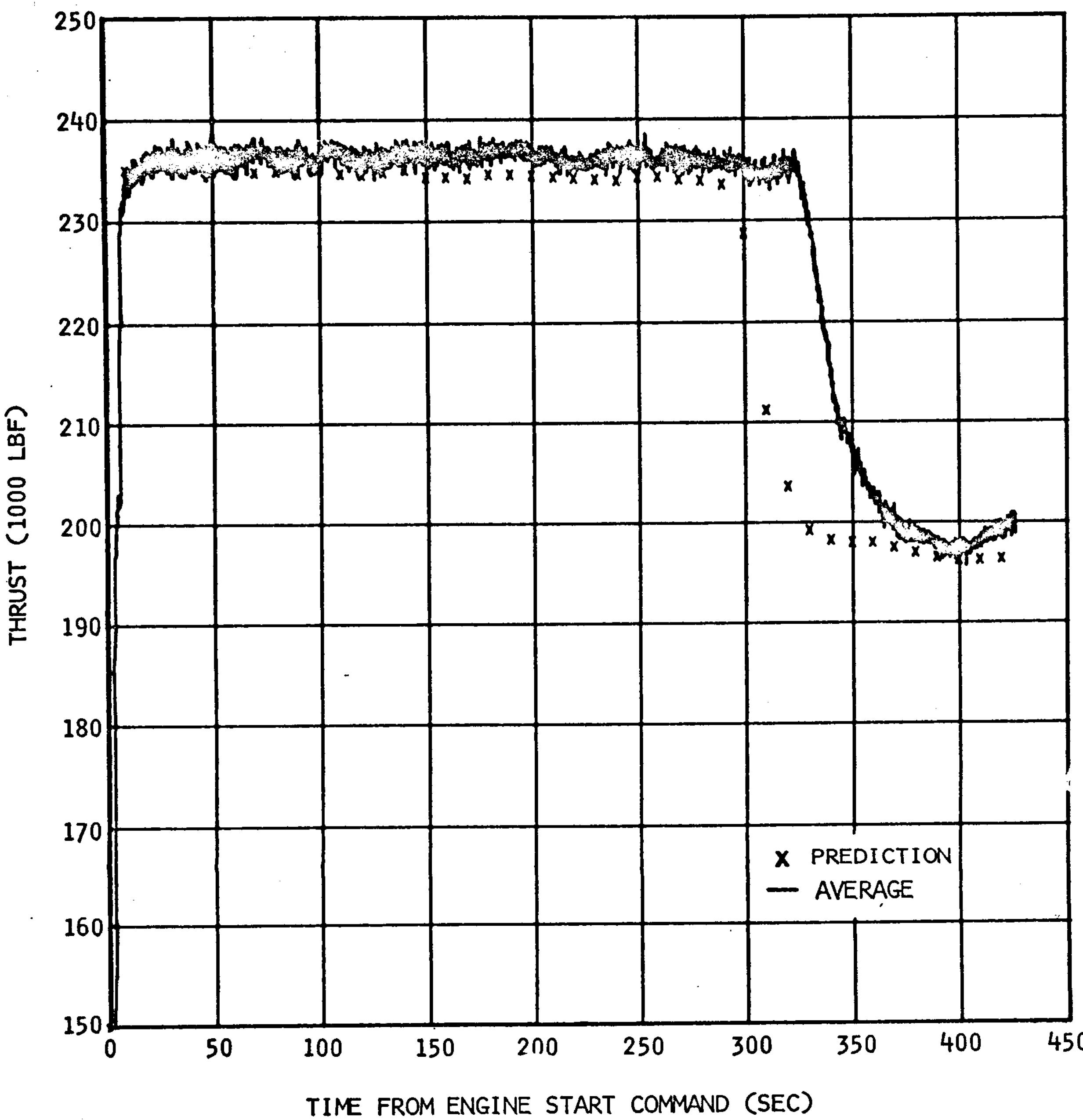

Figure 6-12. J-2 Engine Thrust History

27 March 1967

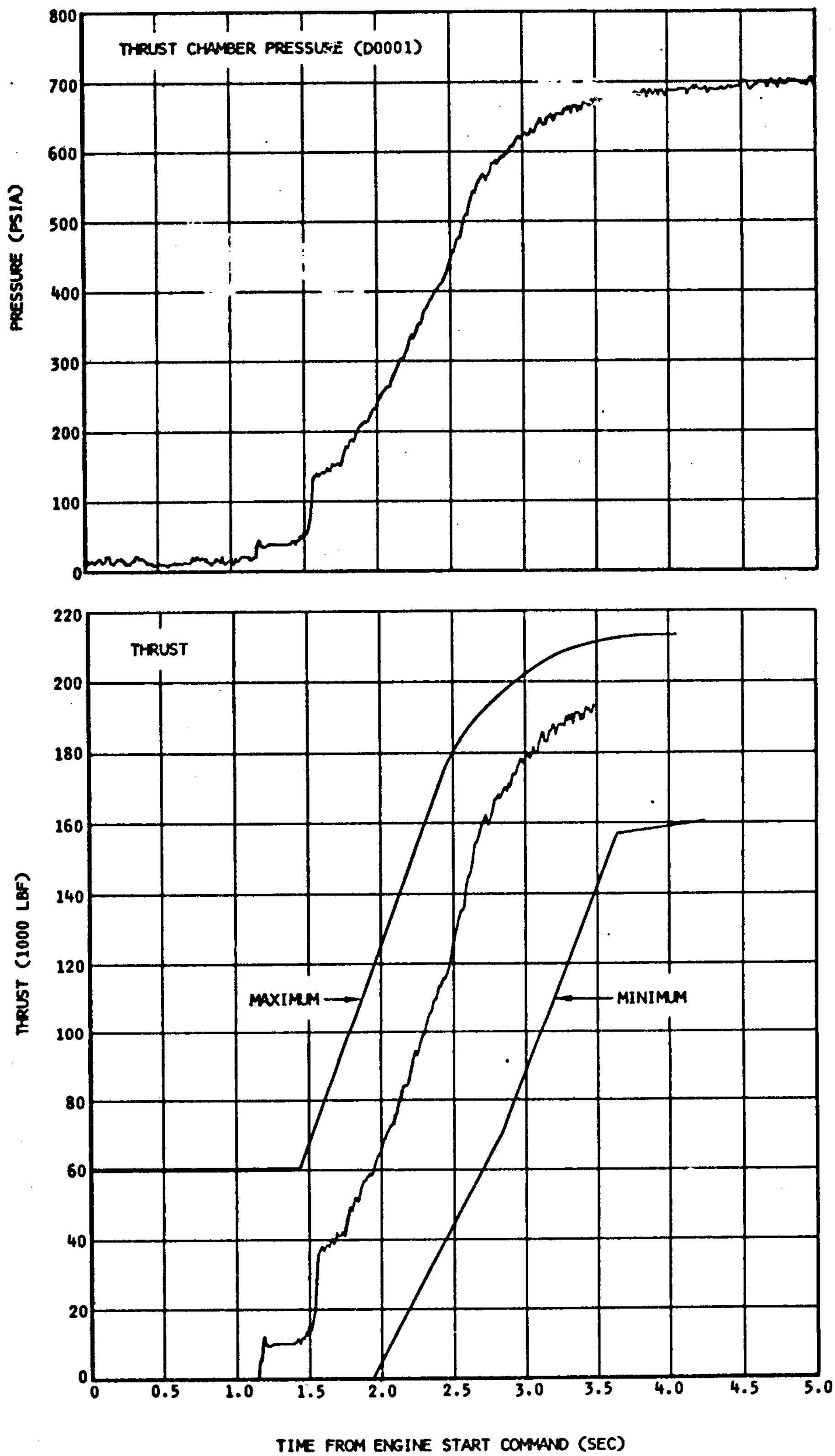

Figure 6-13. Engine Start Transient Characteristics

27 March 1967

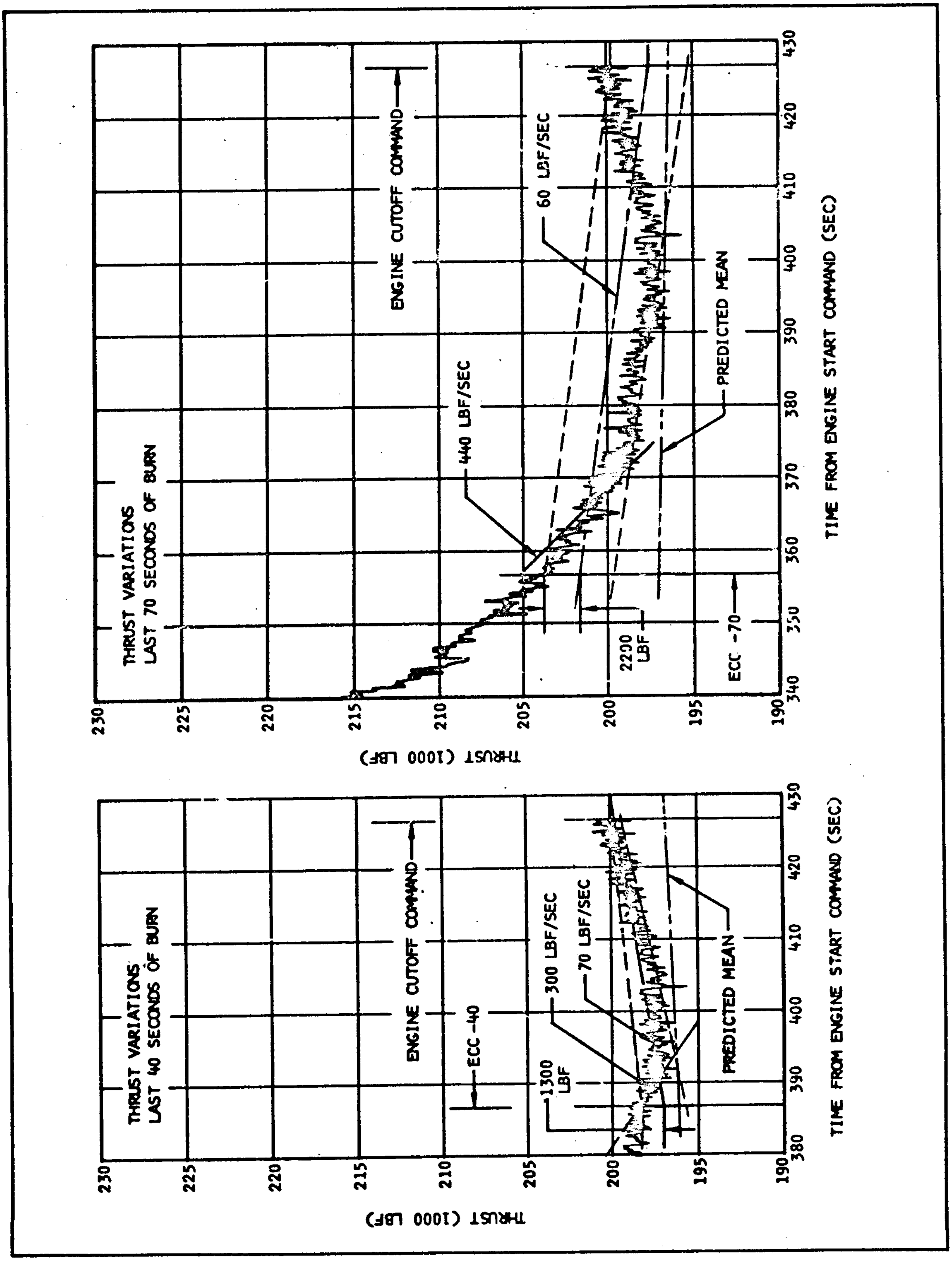

Figure 6-14. Thrust Variations

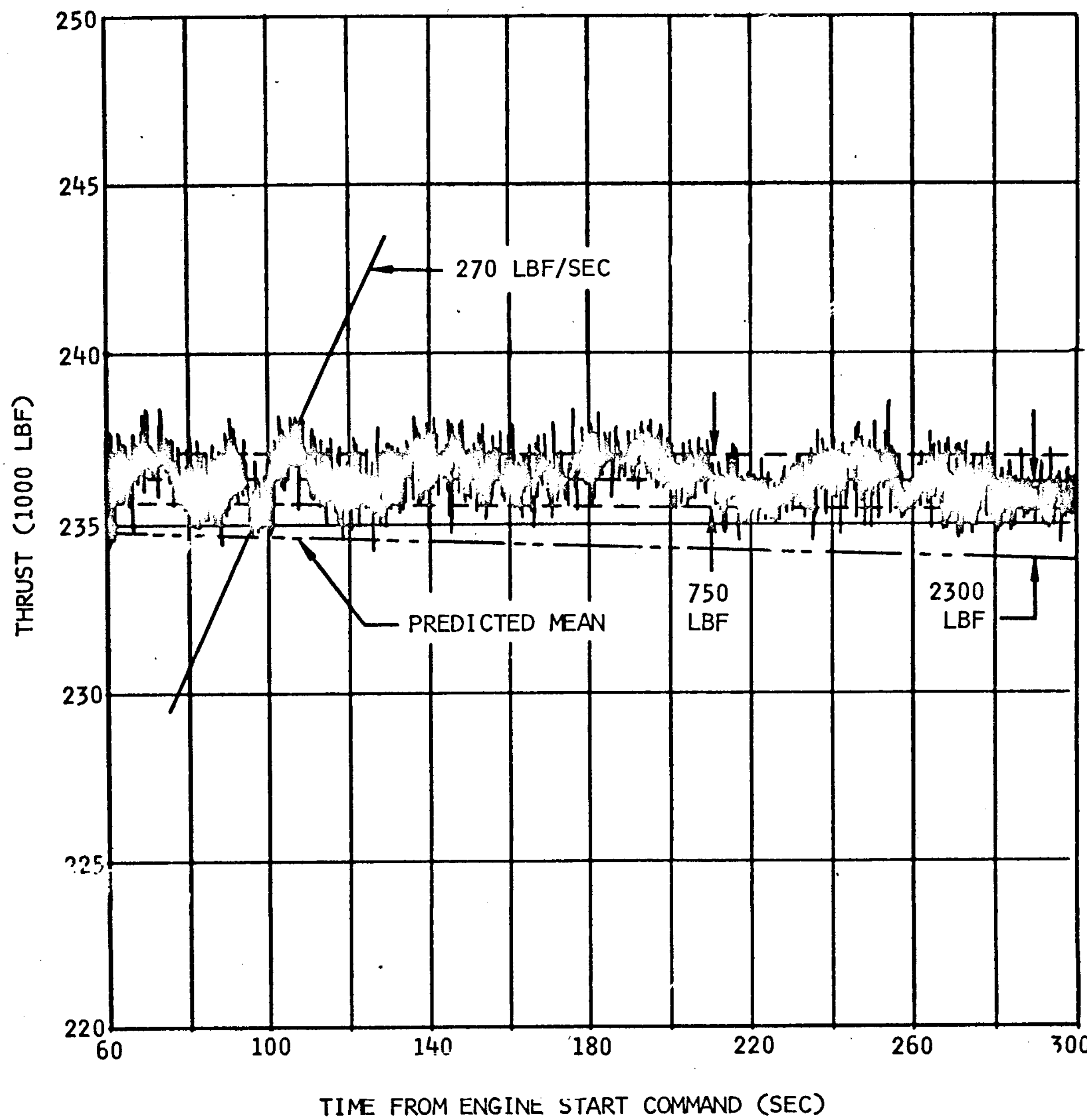

Figure 6-15. Thrust Variations Hardover (5.5/1.0 EMR)

27 March 1967

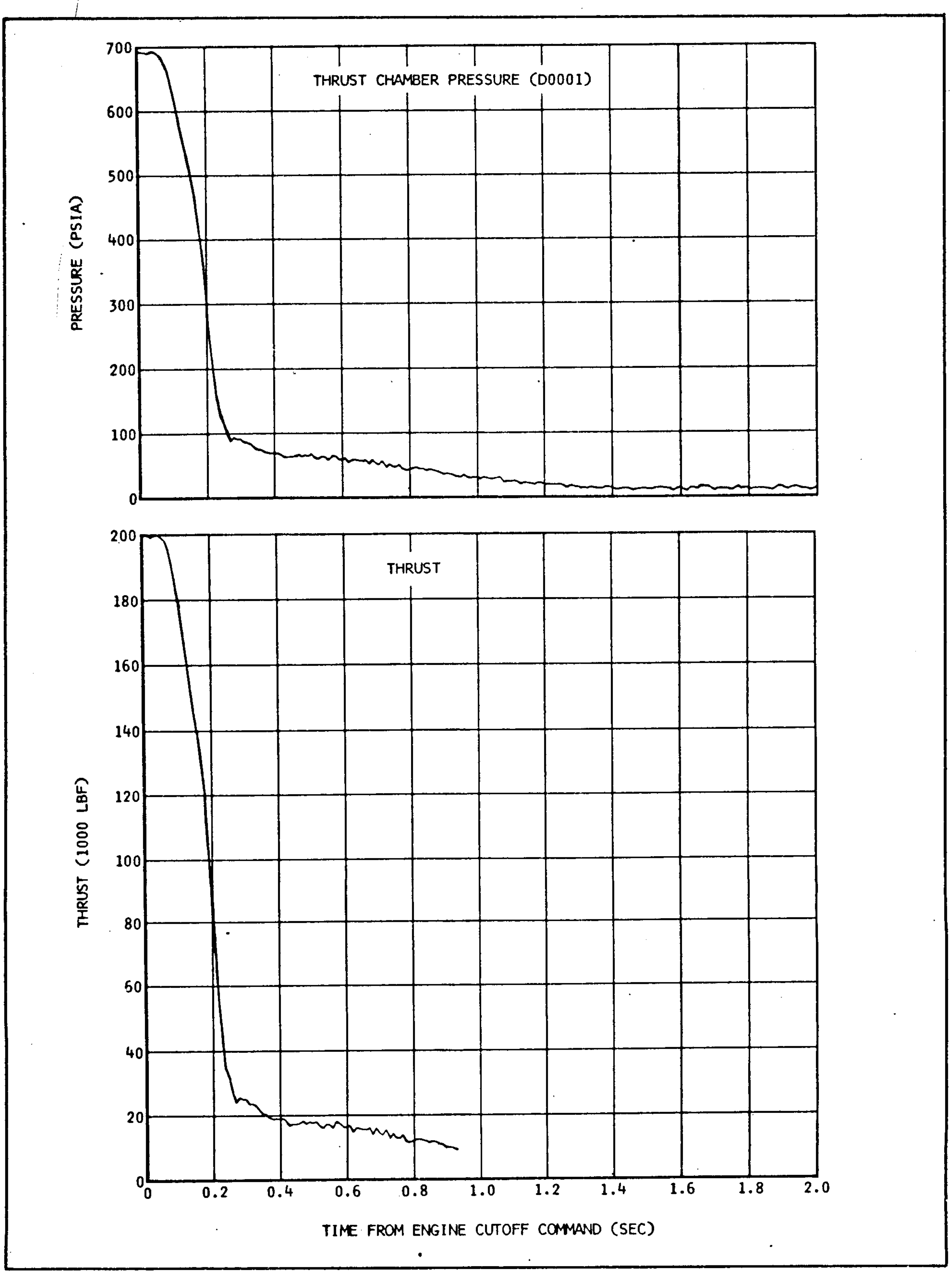

Figure 6-16. Engine Cutoff Transient Characteristics

27 March 1967

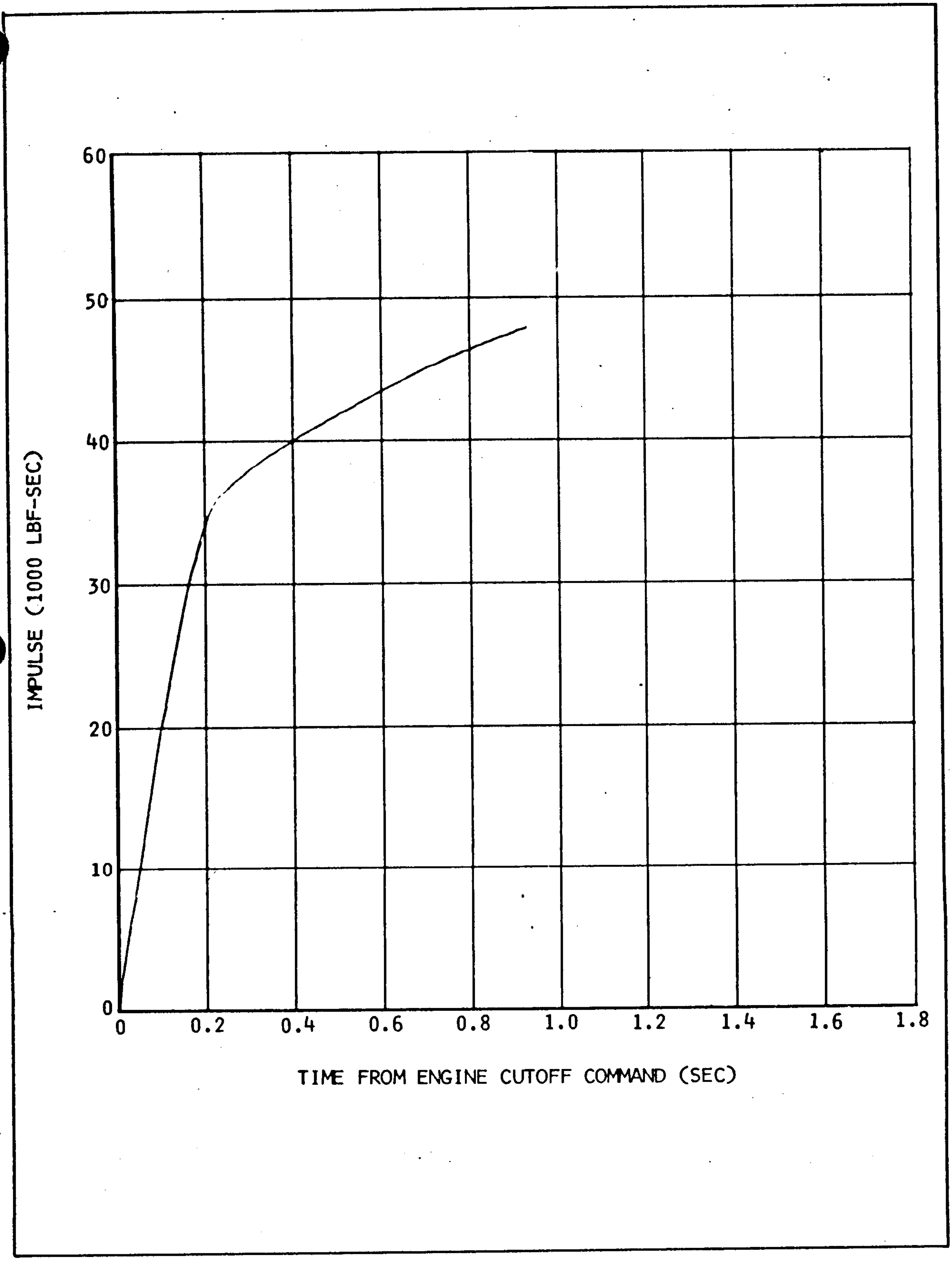

Figure 6-17. Total Accumulated Impulse After Engine Cutoff Command

27 March 1967

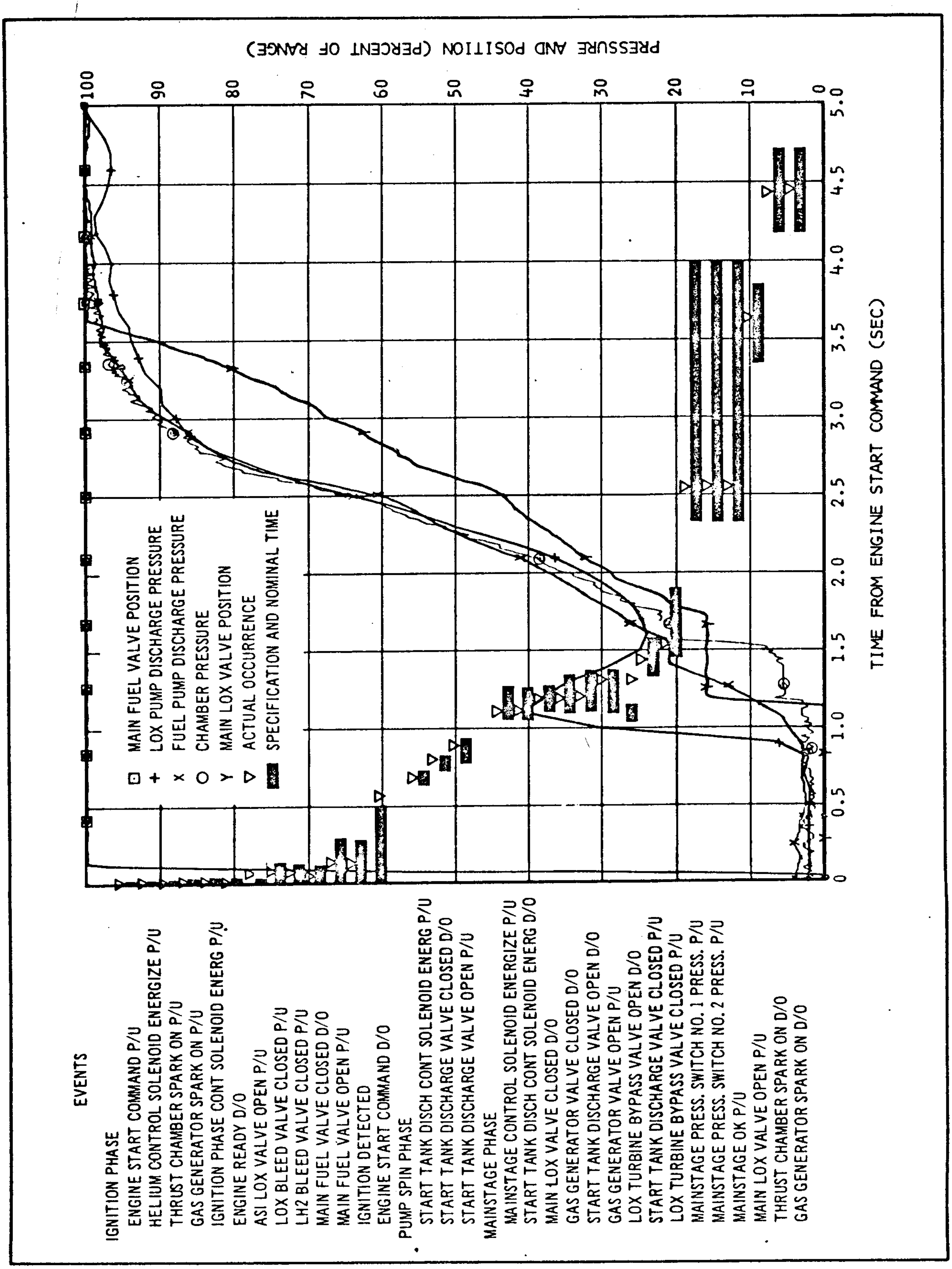

Figure 6-18. Engine Start Sequence

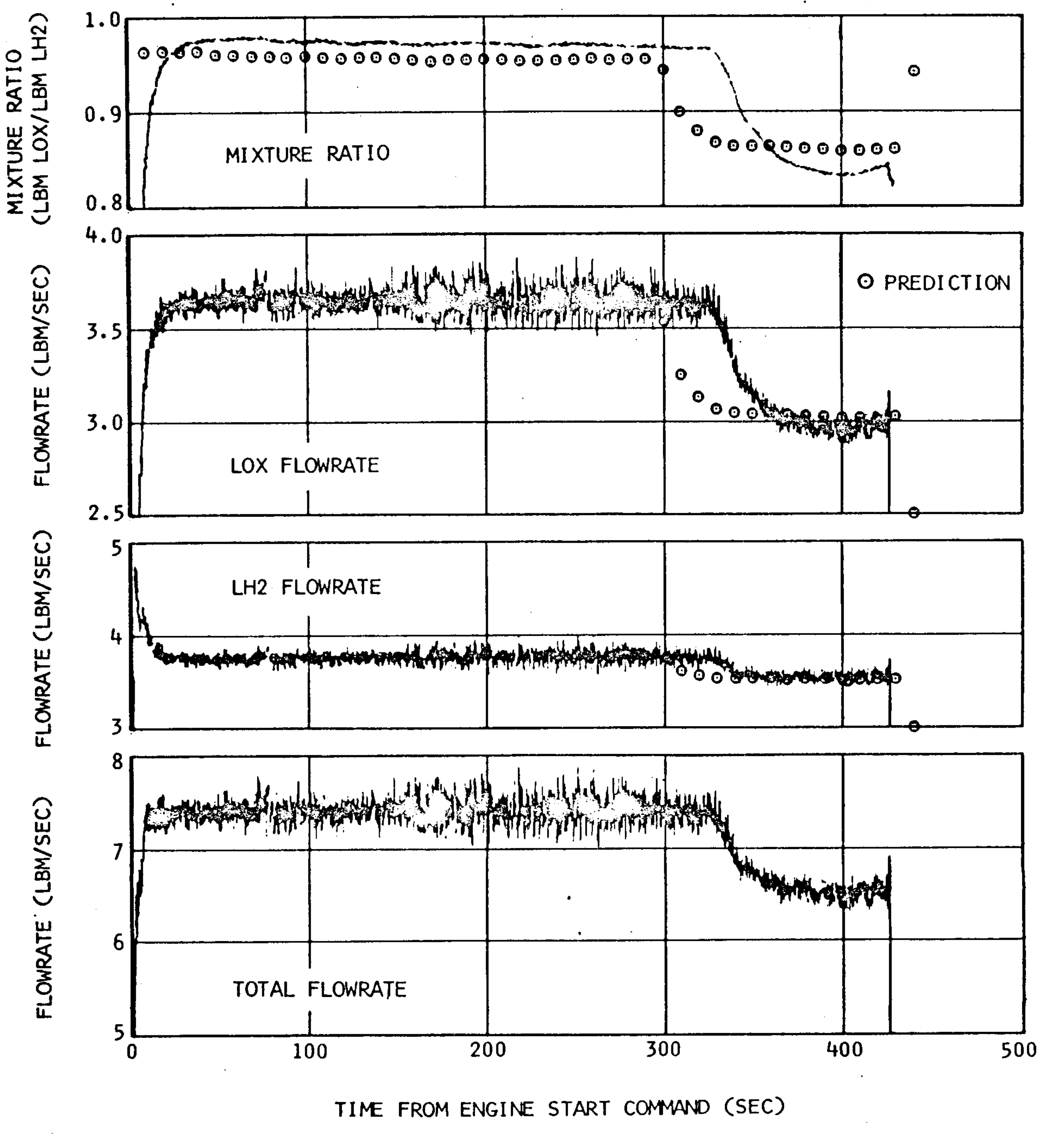

Figure 6-19. Gas Generator Performance

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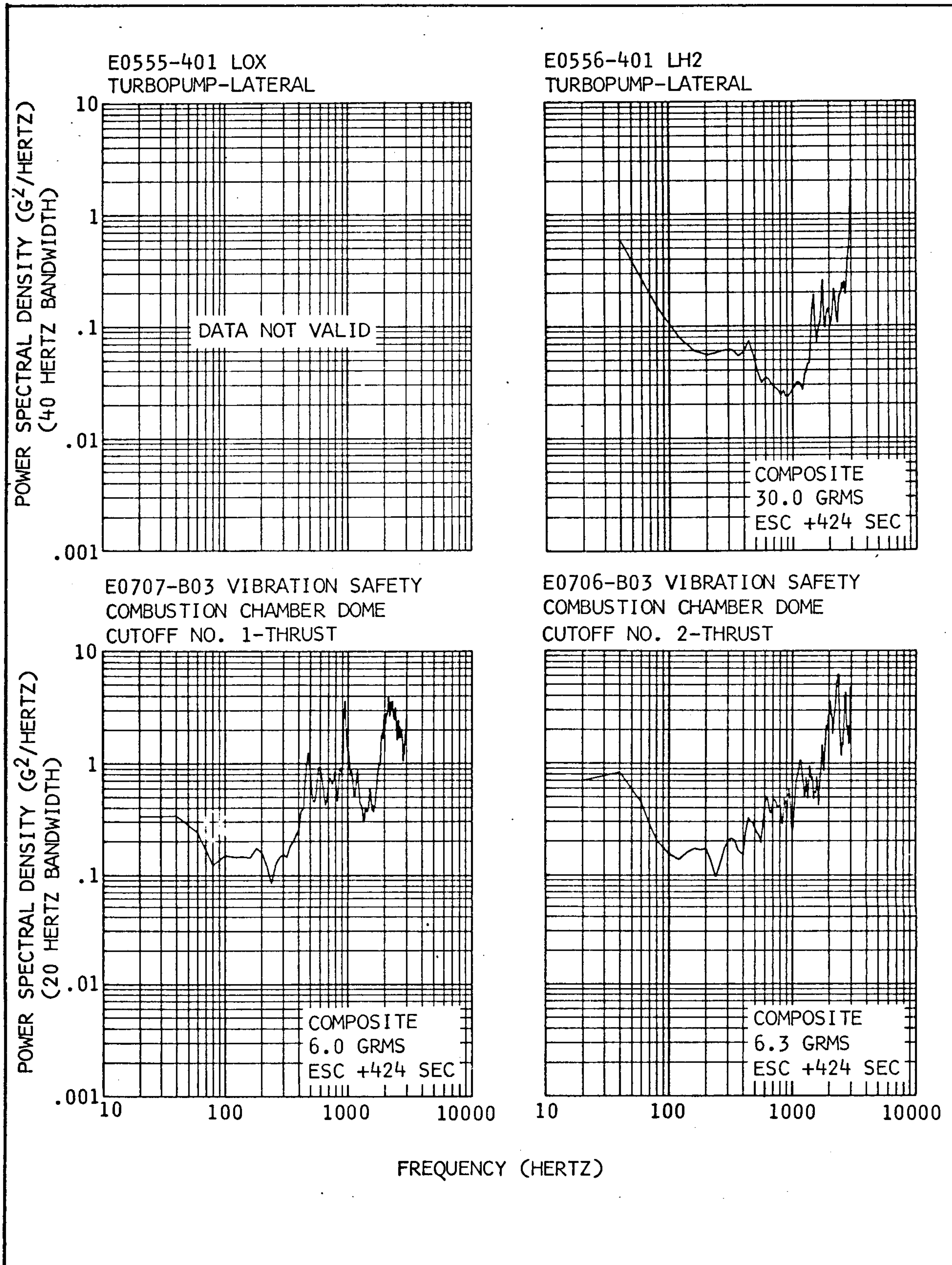

Figure 6-20. Engine Vibration

7. OXIDIZER SYSTEM

The oxidizer system functioned adequately, supplying LOX to the engine pump inlet within the specified limits. The net positive suction head (NPSH) available at the LOX pump inlet exceeded the engine manufacturer's minimum requirements at all times.

7.1 Pressurization Control

The LOX tank pressurization system (figure 7-1) satisfactorily maintained pressure in the LOX tank throughout the acceptance firing. All portions of the system performed close to the design requirements except for the cold helium regulator in the LOX tank pressurization control module, which operated outside of specification.

7.1.1 Prepressurization

LOX tank prepressurization and pressure makeup cycles before simulated liftoff were accomplished from Ground Support Equipment console "B" cold helium supply (figure 7-2). Helium purges of the vent valve and the LOX tank ullage pressure sensing line increased the ullage pressure to the vent relief setting as usual. The hardwire ullage pressure measurement (D0540) indicated high due to back pressure caused by a calibration valve in the sense line. The valve was located downstream of the sense line and purge line junction. Table 7-1 compares significant LOX tank prepressurization data from two previous acceptance firings.

7.1.2 Pressurization

The operation of the LOX tank pressurization system was near nominal (figure 7-3) during engine firing and compared well with that of previous stages except during the start transient. At engine start command, the ullage pressure was 41.4 psia. During the start transient, a greater than normal pressure decrease (34.25 psia) occurred due to a lower control regulator outlet pressure and to the increased LOX flow to the uprated engine. Secondary flow was required six times to maintain the ullage pressure within the range of 37.5 to 39.5 psia during the firing instead of the predicted seven times. Table 7-2 compares the S-IVB-208 stage pressurization system data with that from two previous acceptance firings.

During the fifth interval of secondary flow, the control regulator also failed to respond or open normally, and the LOX tank pressurization module outlet pressure dropped 30 psia below the overcontrol regulated pressure level for approximately 2 to 3 sec. The malfunction appears to be a component problem. The pressurization module is being removed and inspected to determine the source of the two anomalies and will be replaced if necessary.

The pressurization module outlet pressure (D0105) was slightly below specifications (385 $\pm$25 psia) during the first 240 sec of engine operation, and the cold helium flowrate was slightly low. Both of these anomalies were due to the low regulator pressure.

7.2 Cold Helium Supply

At engine start command, the cold helium spheres contained 254 lbm of helium at 3,046 psia and 40.0 deg R. The conditions of the cold helium spheres at significant times are presented in table 7-2. The temperature and pressure profiles were normal and are shown in figure 7-4.

7.3 J-2 Heat Exchanger

The J-2 heat exchanger functioned satisfactorily (figure 7-5). The performance was not significantly affected by the temperature of the entering combustion products, which was higher than usual because of the uprating of the J-2 engine (section 6) and the corresponding increase of the gas generator combustion temperature. The measured LOX vent inlet temperature and the theoretical mixture temperature compared reasonably well with previous test data. Table 7-3 compares significant S-IVB-208 stage heat exchanger data with that from two previous acceptance firings.

7.4 LOX Pump Chilldown

The LOX pump chilldown system performance was adequate. At engine start command, the NPSH at the LOX pump inlet was above the minimum required at that time. The chilldown system data and the results of the performance calculations are presented in figures 7-6 and 7-7 and compared with data from two previous acceptance firings in table 7-4.

The chilldown pump was started 602 sec prior to simulated liftoff in order to more closely simulate conditions during flight. The shutoff valve was left open until a few seconds before cutoff, showing that the LOX supply system could operate adequately with the valve open.

A microswitch talkback failure occurred and made it necessary to examine the LOX flowrate and other appropriate measurements to determine if the LOX shutoff valves had actually opened. This failure was caused by a leak in the seal of the microswitch cover gasket, which allowed moisture or air to cryopump into the switch housing. A redesign of this part has been proposed.

The calculated heat input to section 1 (tank to turbopump inlet) appeared to be abnormally high, primarily because the LOX chilldown pump outlet temperature (C0163) was indicating low. Investigation revealed that, during burn (when the shutoff valve is open and the flowrate from the tank to the turbopump is high) this temperature should be nearly the same as the LOX turbopump inlet temperature (C0004), but was 1.8 deg lower instead. The bleed valve temperature (C0651) was also consistently 0.9 deg below the saturation temperature before the chilldown pump was started. It was lower than the pump discharge pressure during burn as well, indicating that the temperature should be adjusted. Therefore, these biases (1.8 and 0.9 deg R) were applied for the heat input calculations. The results are more realistic and are compared to data from two previous acceptance firings in table 7-4 and as follows:

HEAT INPUT RATES (BTU/HR)

SECTION	CALCULATED FROM RAW DATA	CALCULATED FROM C0163 AND C0651 WITH BIAS	AVERAGE OF S-IVB -204, -205, AND -206
1. (tank to turbopump inlet)	20,500	4,000	4,170
2. (pump inlet to bleed valve)	5,000	14,000	13,000
3. (bleed valve to tank inlet)	10,000	2,000	2,330
Total	35,500	20,000	19,500

7.5 Engine LOX Supply

The LOX supply system (figure 7-8) delivered the necessary quantity of LOX to the engine pump inlet throughout the engine firing and maintained the pressure and temperature conditions within a range that provided a LOX pump NPSH above the minimum requirements. The data and calculated performance are presented in figure 7-9. Table 7-5 compares S-IVB-208 stage data and calculated performance with that from two previous acceptance firings.

During engine operation, the LOX pump inlet pressure and temperature were very near the predicted values, although during the pressurization system start transient, the pump inlet pressure and, consequently, the NPSH dropped lower than had been anticipated. The primary factor affecting the pump inlet pressure is the ullage pressure, which is discussed in paragraph 7.1.2.

The LOX pump inlet pressure and temperature were plotted in the engine LOX pump operating region (figure 7-10) and showed that the engine LOX pump inlet conditions were met satisfactorily throughout engine operation.

In figure 7-11, the pump inlet temperature is plotted against the mass remaining in the LOX tank during engine operation and is compared to the S-IVB-206 and -207 test data biased to an identical initial condition. It is apparent that the heat transfer to the LOX was very similar to that noted on the previous firings.

7.6 LOX Tank Vent and Relief Valve Operation

The LOX tank vent and relief valve performance was satisfactory, as determined during the terminal count. During the LOX tank vent and relief test, the valve appeared to crack at 41.9 psia and reseat at 39.7 psia. Evaluation indicated the abnormally wide dead band of 2.2 psia was the result of an inaccurate pressure measurement. The sense line purge on the ullage pressure measurement active at that time (D0540) apparently made the pressure indications unreliable and inconsistant. These data were thus disregarded.

During the terminal count, an ullage pressure sensor with an unpurged sense line was indicating 42.5 psia when the valve cracked as a result of the ambient helium purges flowing into the tank; the valve reseated at 42.2 psia. These values indicate that the vent and relief performance was satisfactory.

TABLE 7-1
LOX TANK PREPRESSURIZATION

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
Prepressurization initiation (sec from ESC)	-312	-311	-315
Prepressurization duration (sec)	13	16	19
Number of makeup cycles	1	1	2
Prepressurization flowrate (lbm/sec)	0.25 to 0.35	0.22 to 0.32	0.22 to 0.30
Helium added to LOX tank during main prepressurization (lbm)	3.3	4.00	3.87
Helium added to LOX tank during makeup cycles (lbm)	1.9	0.66	0.65
Ullage pressure at prepressurization initiation (psia)	14.7	15.2	15.0
Ullage pressure at prepressurization termination (psia)	40.2	40.5	39.2
Ullage pressure at engine start (psia)	38.3	41.9	41.4

TABLE 7-2 (Sheet 1 of 2)
LOX TANK PRESSURIZATION

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
Ullage pressure at engine start (psia)	38.3	41.9	41.4
Minimum ullage pressure during start transient (psia)	32.9	36.3	34.25
Number of secondary flow intervals	6	7	6
LOX tank pressure control band (psia)	36.9 to 38.9	37.43 to 39.45	37.5 to 39.5
LOX tank pressurization total flowrate:			
During overcontrol (lbm/sec)	0.38 to 0.44	0.39 to 0.48	0.36 to 0.44
Predicted (lbm/sec)	0.34 to 0.40	0.42 to 0.46	0.39 to 0.47
During undercontrol (lbm/sec)	0.27 to 0.31	0.28 to 0.36	0.26 to 0.32
Predicted (lbm/sec)	0.23 to 0.26	0.29 to 0.33	0.27 to 0.32
Helium in cold helium spheres at Engine Start Command (lbm)	251	254	254
Cold helium sphere pressure at Engine Start Command (psia)	3,020	2,990	3,046
Average cold helium sphere temperature at Engine Start Command (deg R)	40.0	39.7	40.0
Helium in cold helium spheres at Engine Cutoff Command (lbm)	91	97	100
Helium consumed during engine firing as calculated from sphere conditions (lbm)	160	157	154
Helium consumption calculated by integration of flowrate (lbm)	148	155	142

TABLE 7-2 (Sheet 2 of 2)
LOX TANK PRESSURIZATION

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
Cold helium sphere pressure at Engine Cutoff Command (psia)	700	640	648
Average cold helium sphere temperature at Engine Cutoff Command (deg R)	47.3	44.8	42.2
Estimated temperature loss in 10 feet of uninsulated line:			
During overcontrol (deg R)	14	7	11
During undercontrol (deg R)	38	17	28
Maximum LOX tank vent inlet temperature* (deg R)	530	496	506

*Redline is 560 deg R.

TABLE 7-3
J-2 HEAT EXCHANGER PERFORMANCE DURING HIGH EMR PORTION OF FIRING

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
Flowrate through heat exchanger:			
During overcontrol (lbm/sec)	0.187 to 0.205	0.215	0.20
During undercontrol (lbm/sec)	0.072	0.085	0.080
Heat exchanger inlet temperature:			
During overcontrol (deg R)	60	60	60
During undercontrol (deg R)	70	73	70
Heat exchanger outlet temperature*:			
During overcontrol (deg R)	974	957	980
During undercontrol (deg R)	1,028	1,002	1,000
Heat exchanger outlet pressure:			
During overcontrol (psia)	338 to 368	335 to 360	315 to 345
During undercontrol (psia)	395 to 420	385 to 407	380 to 400
Heat exchanger outlet temperature at engine cutoff (deg R)	930	902	906
Average LOX vent inlet pressure:			
During overcontrol (psia)	68	72	69
During undercontrol (psia)	48	51	51

* Estimated from measurement C0009 and uninsulated line temperature loss.

TABLE 7-4
LOX CHILLDOWN SYSTEM PERFORMANCE

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
NPSH at Engine Start Command (psi)	30.3	33.2	32.0
NPSH at start of chilldown (psi)	5.7	5.0	5.0
Minimum required at engine start (psi)	16.5	16.5	16.5
NPSH at opening of prevalve (psi)	39.7	41.9	40.4
Average flow coefficient (sec^2/in^2ft^3)	16.7	15.3	15.6
Pump inlet pressure at engine start (psia)	47.2	50.0	49.5
Pump inlet temperature at engine start (deg R)	165.3	164.6	165.6
Pump inlet temperature at engine cutoff (deg R)	168.0	167.5	167.9
Heat absorption rate (Btu/hr)			
Section 1 (tank to turbopump inlet)	4,000	2,000	4,000
Section 2 (pump inlet to bleed valve)	13,500	14,200	14,000
Section 3 (bleed valve to tank inlet)	1,000	2,800	2,000
Total	18,500	19,000	20,000
Unpressurized chilldown flowrate (gpm)	39.3	36.7	37.7
Pressurized chilldown flowrate (gpm)	41.2	41.0	43.0
Unpressurized pressure drop (psi)	8.4	8.7	8.0
Pressurized pressure drop (psi)	9.8	10.0	10.0
Events (sec from T)			
Chilldown start	-305	-302	-602
Prevalve open command	146.36	146.88	146.39
Prevalve closed signal dropout	147.32	147.50	147.16
Prevalve open signal pickup	149.15	149.08	148.69
Delay between prevalve open command and pickup of signal	2.79	2.26	2.30
Chilldown shutoff valve closed	150	150	566.57
Prepressurization	-160	-161	-165
Engine Start Command	150.77	150.86	150.27
Engine Cutoff Command	586.92	598.94	576.87

TABLE 7-5
LOX PUMP INLET CONDITIONS

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
Pump inlet conditions at engine start:			
Static pressure (psia)	47.2	50.0	49.5
Temperature (deg R)	165.3	165.2	165.6
NPSH requirements:			
At high EMR (psi)	20.2	21.0	20.2
After EMR cutback (psi)	14.3	14.9	14.25
NPSH available:			
At Engine Start Command (psi)	30.3	33.2	32.0
At start transient plus time (psi/sec)	22.3/21	26.0/20	22.8/21
At Engine Cutoff Command (psi)	18.5	21.8	20.7
Minimum and time of occurrence (psi/sec)	18.5/ECO	21.8/ECO	20.7/ECO
Suction duct:			
High EMR Pressure drop (psi)/flowrate (lbm/sec)	2.6/450	1.4/450	1.8/468
After EMR cutback Pressure drop (psi)/flowrate (lbm/sec)	1.7/380	0.4/368	1.3/379

NOTE: SEE FIGURE 3-1 FOR LEGEND

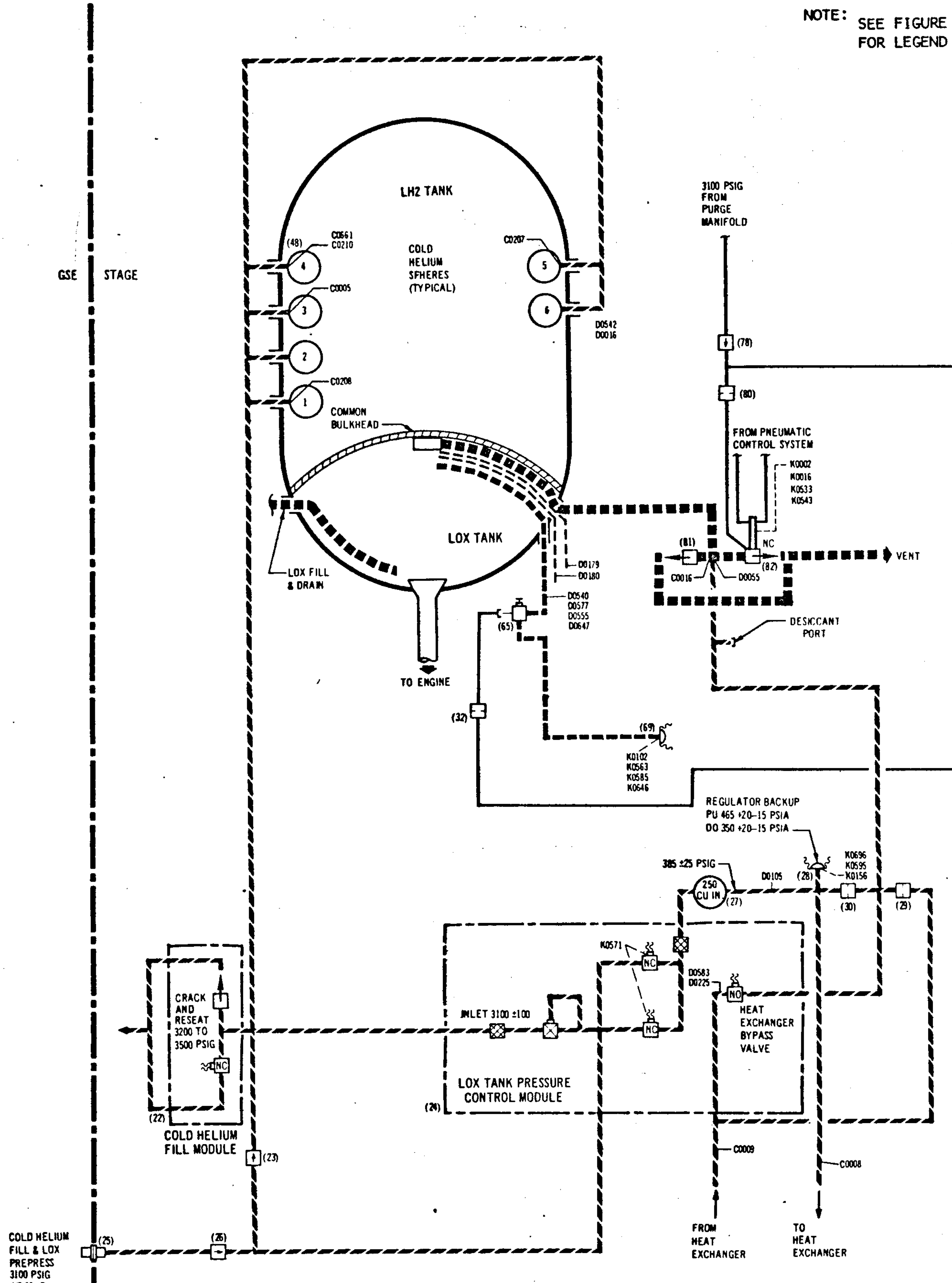

Figure 7-1. LOX Tank Pressurization System

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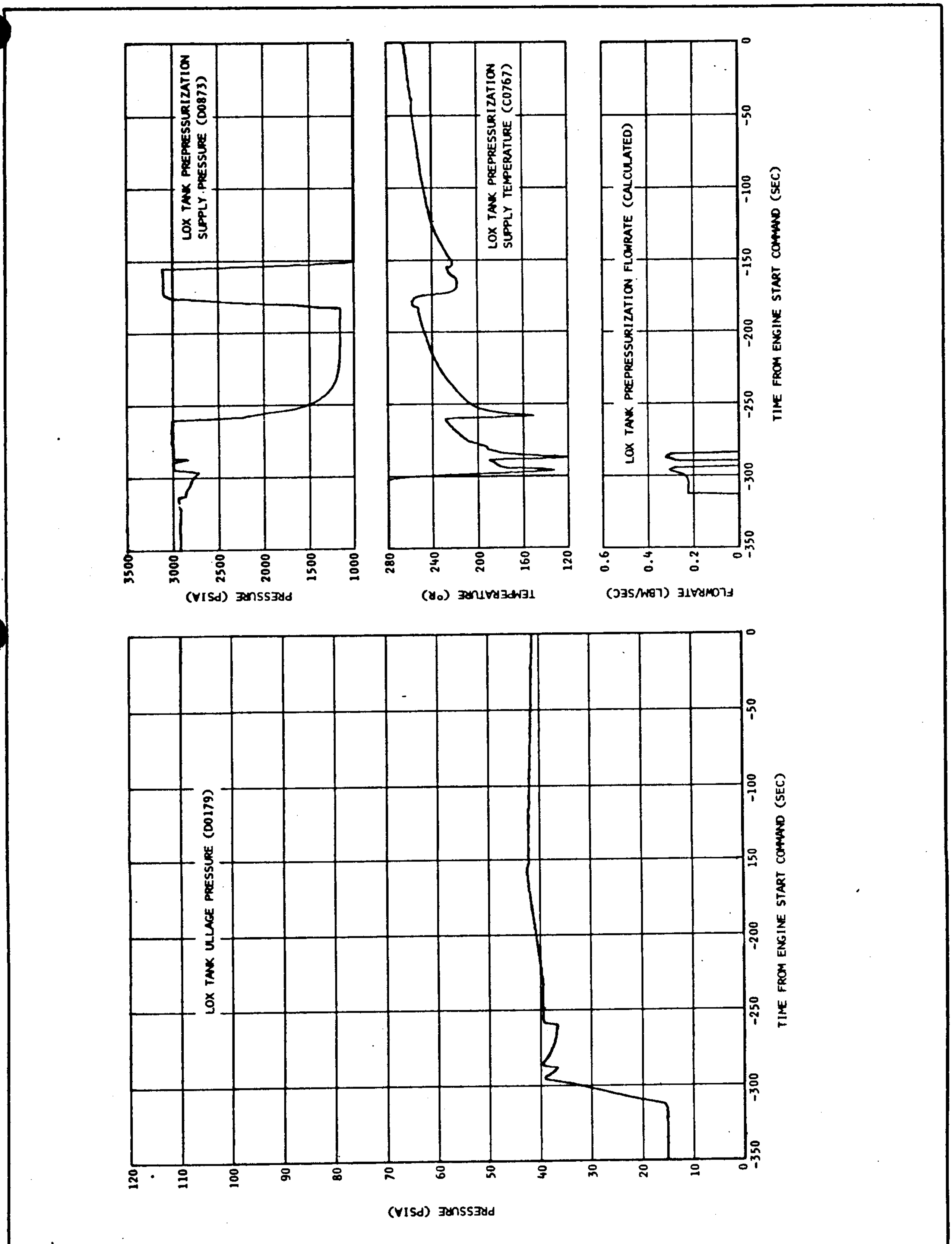

Figure 7-2. LOX Tank Conditions During Prepressurization and Simulated Boost

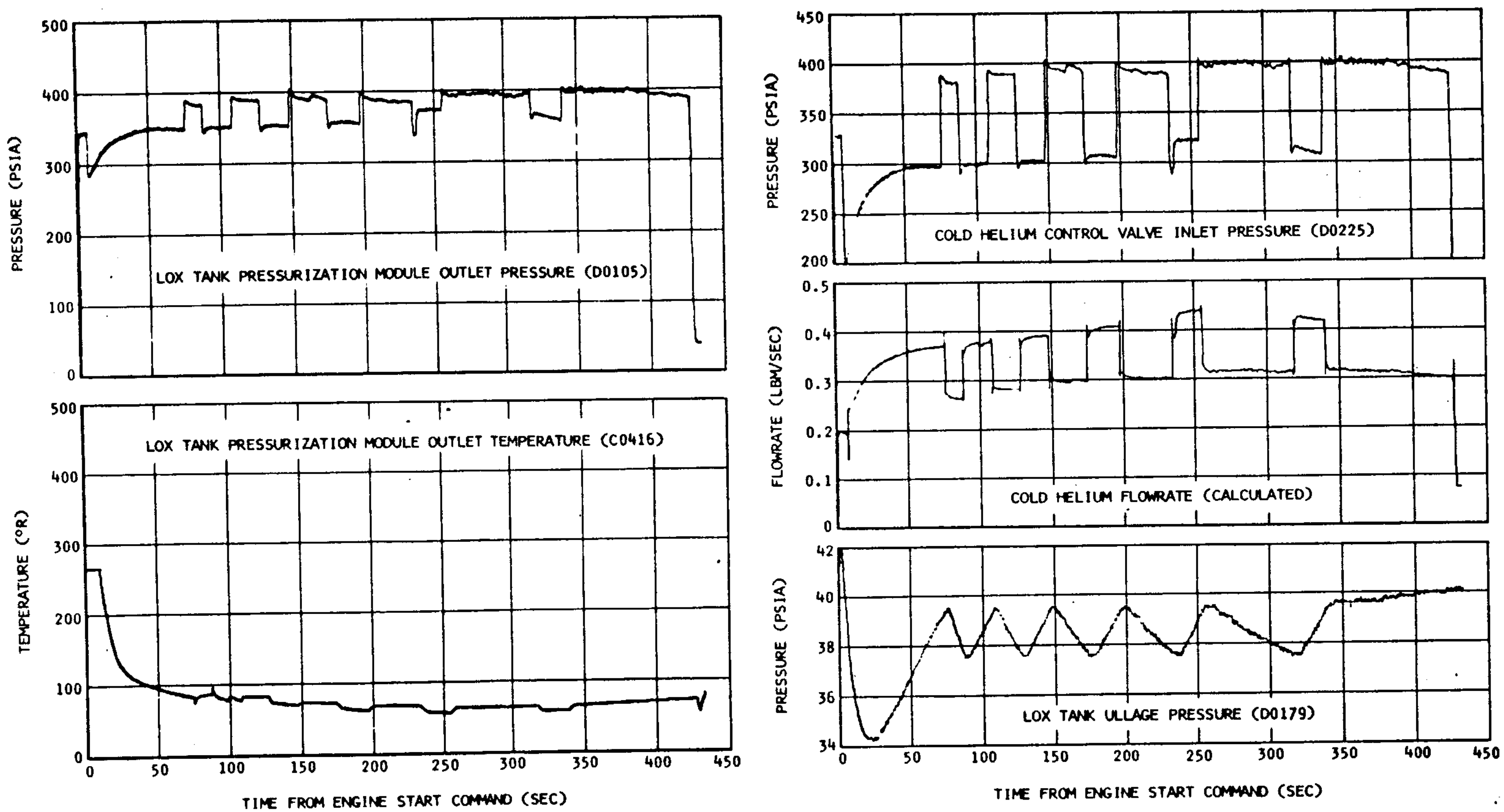

Figure 7-3. LOX Tank Pressurization System Performance

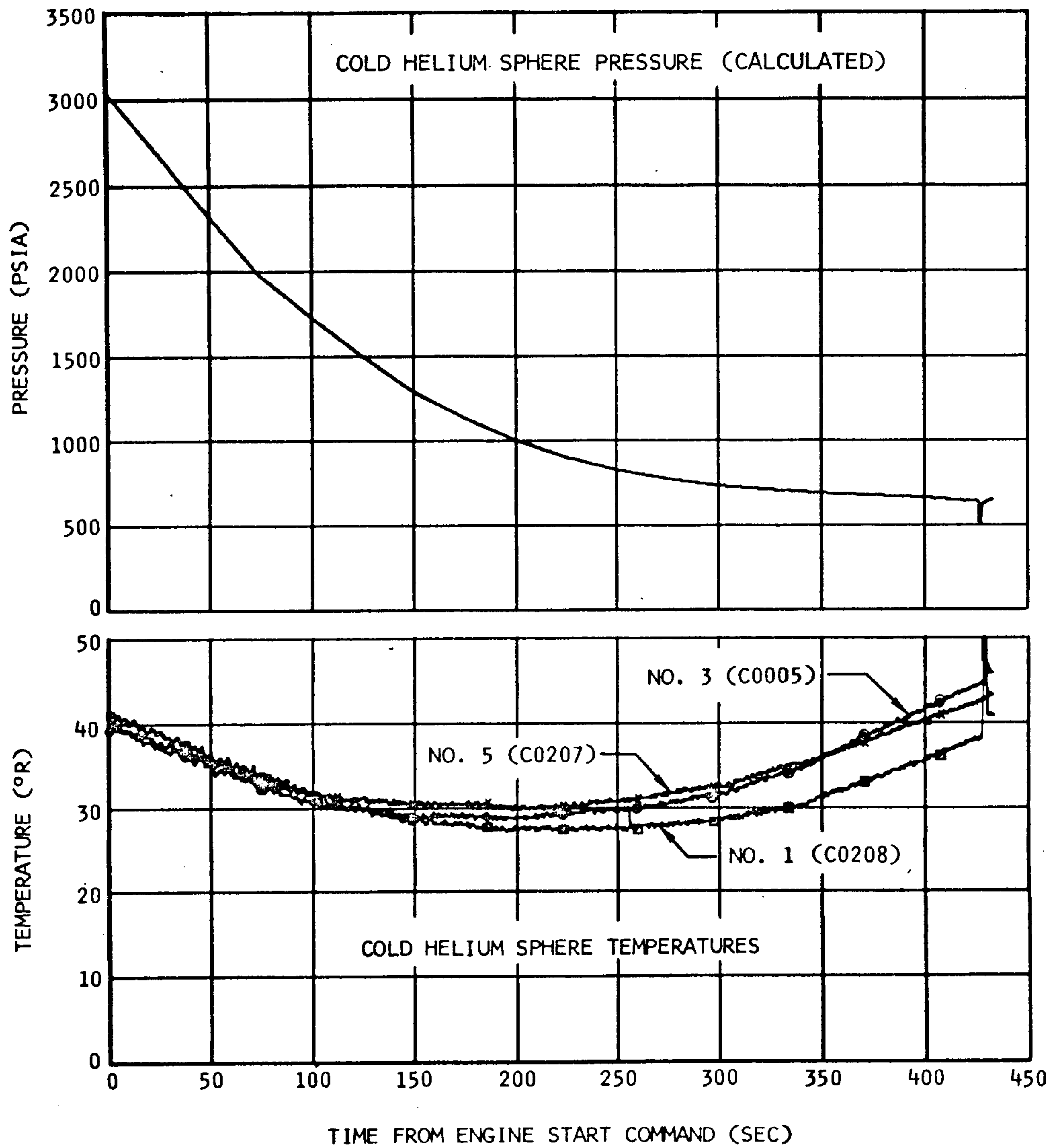

Figure 7-4. Cold Helium Supply

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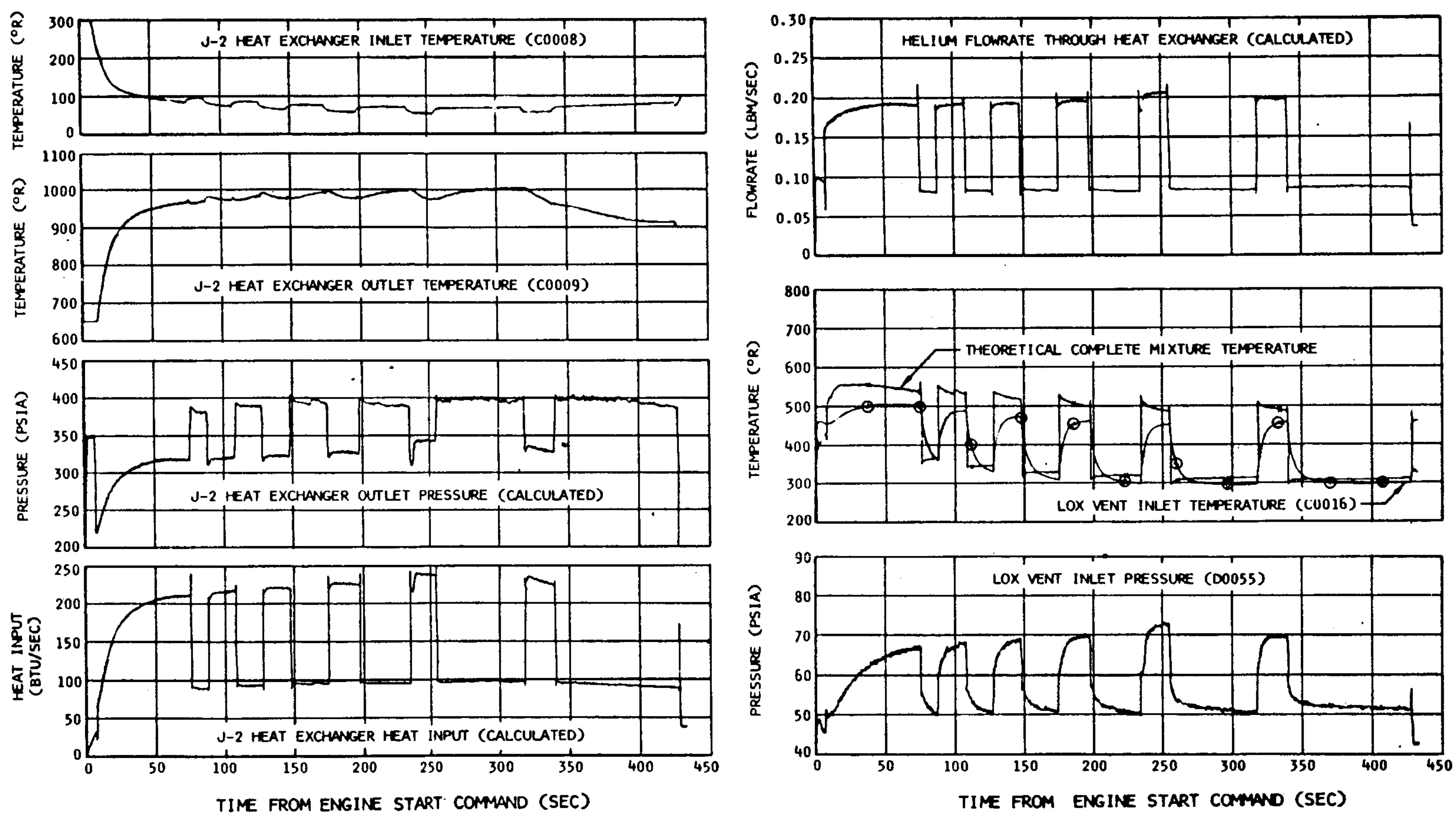

Figure 7-5. J-2 Heat Exchanger Performance

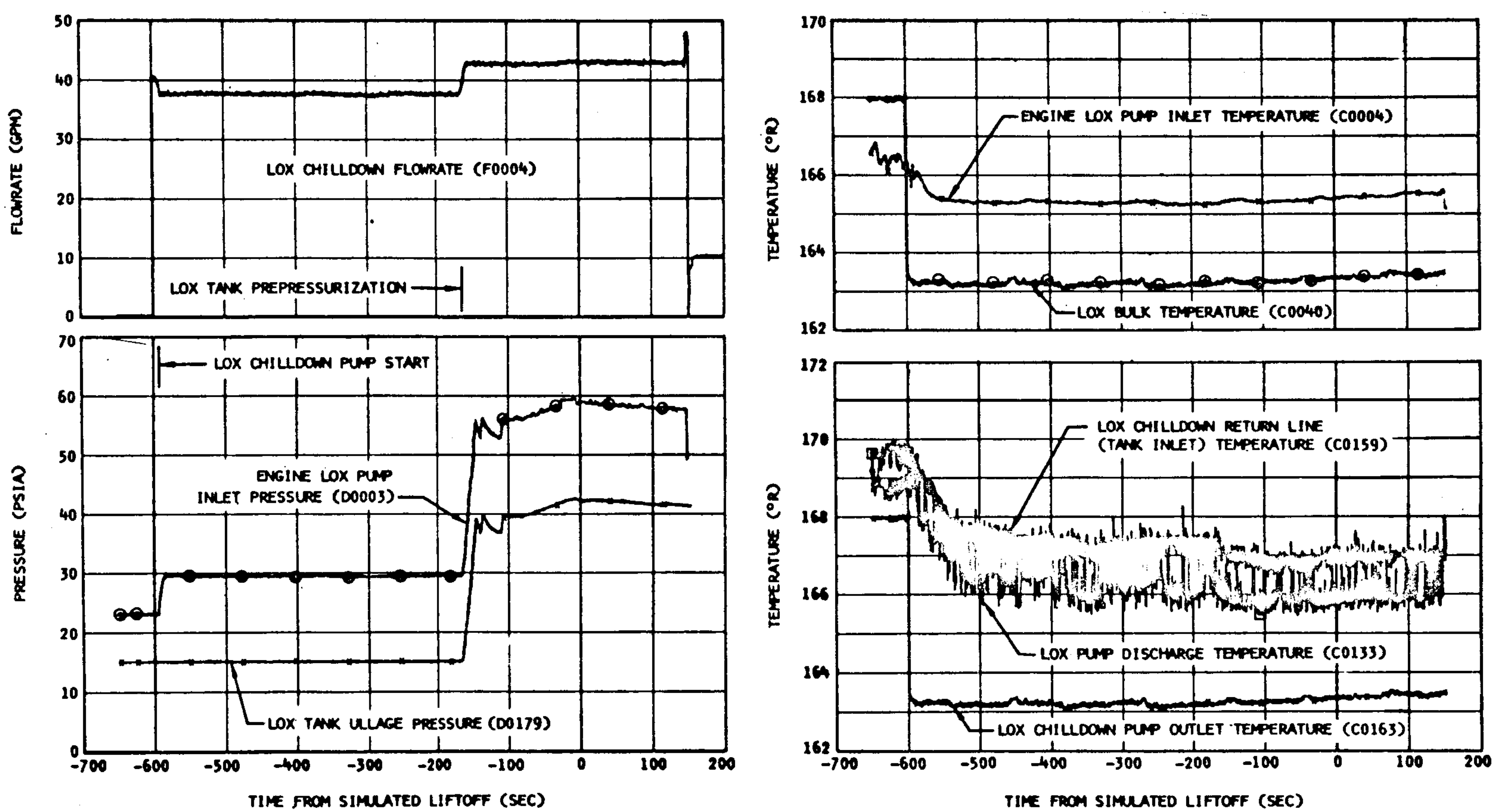

Figure 7-6. LOX Pump Chilldown System Operation

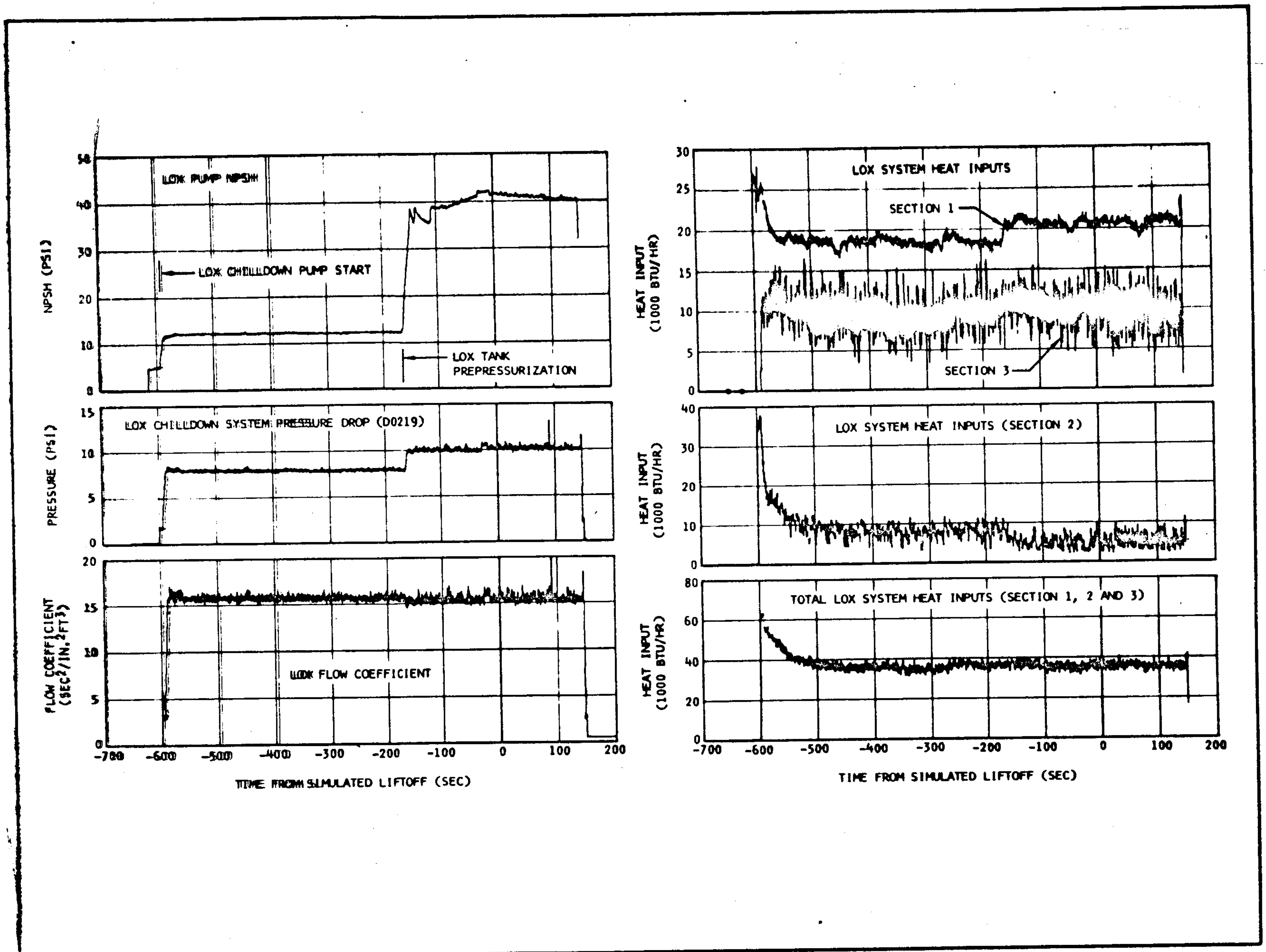

Figure 7-7. LOX Pump Chilldown System Performance

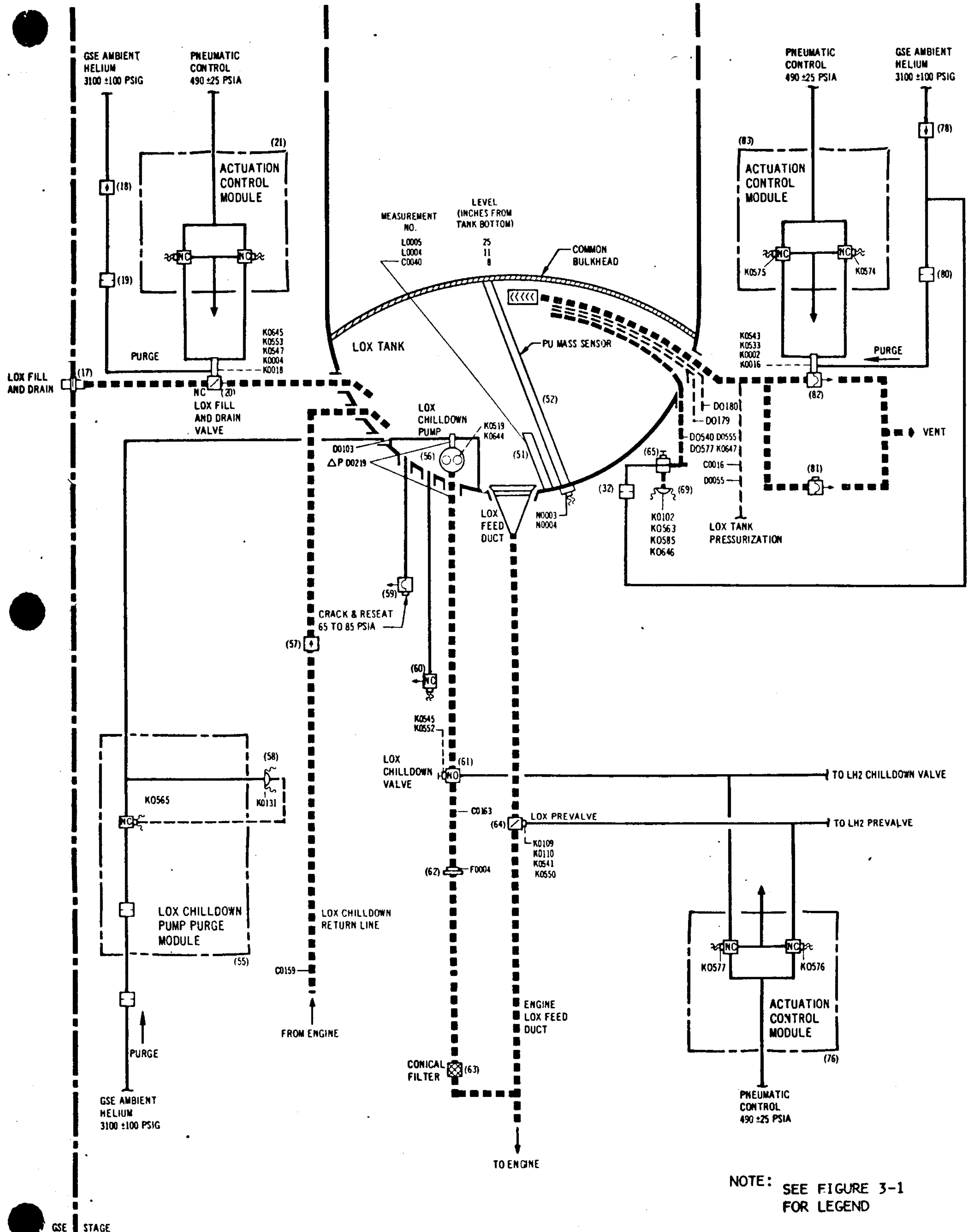

Figure 7-8. LOX Supply System

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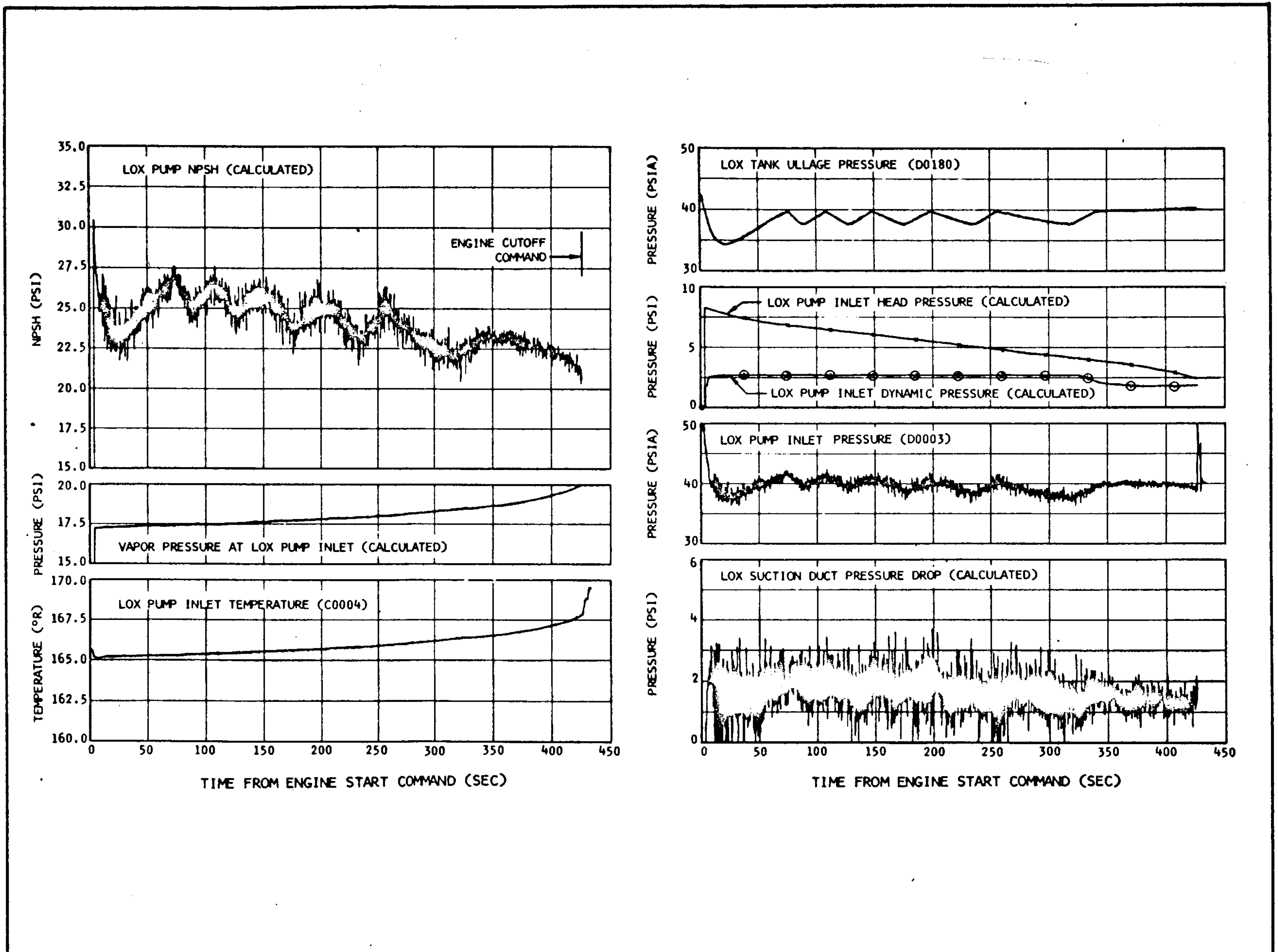

Figure 7-9. LOX Pump Inlet Conditions

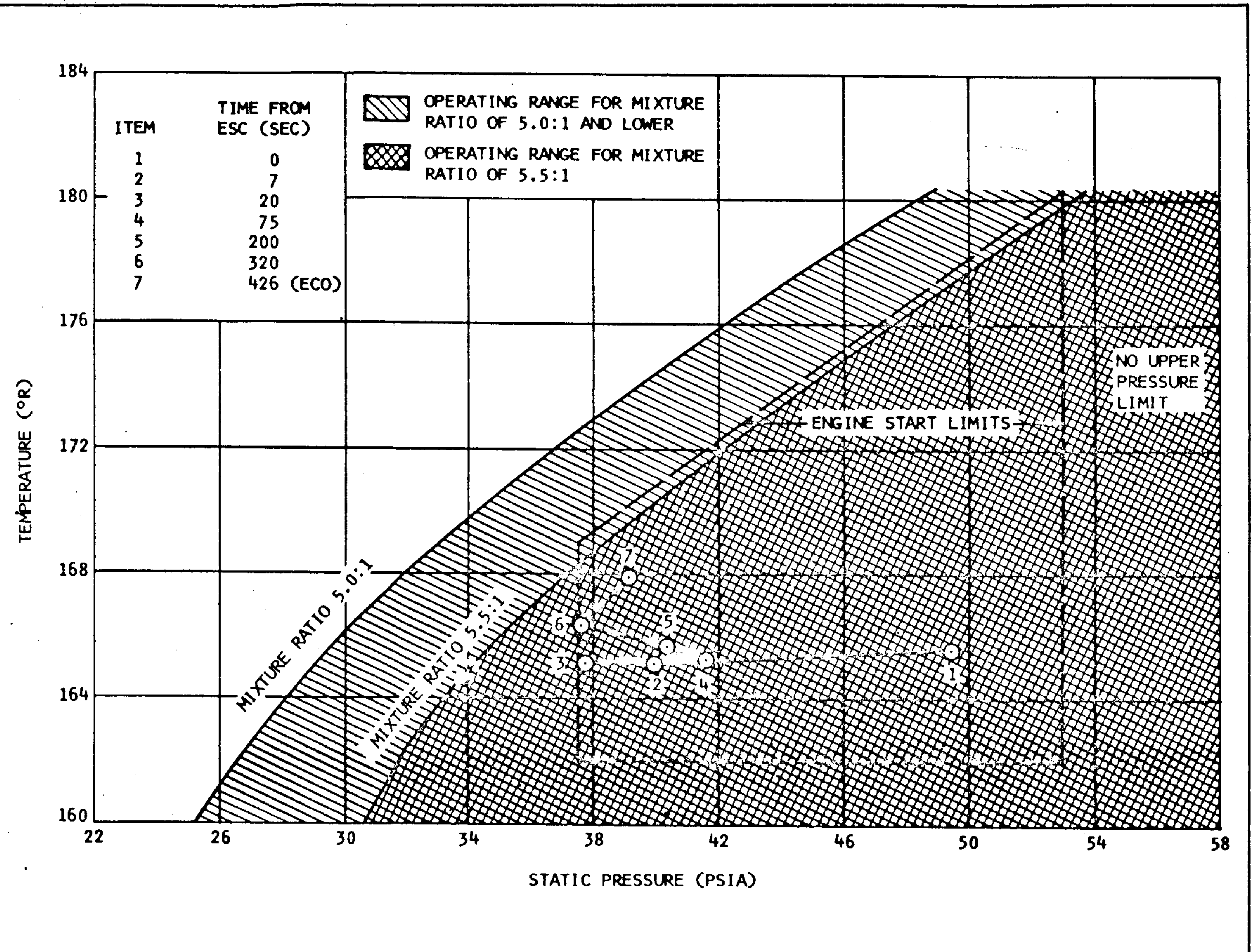

Figure 7-10. LOX Pump Inlet Conditions During Firing

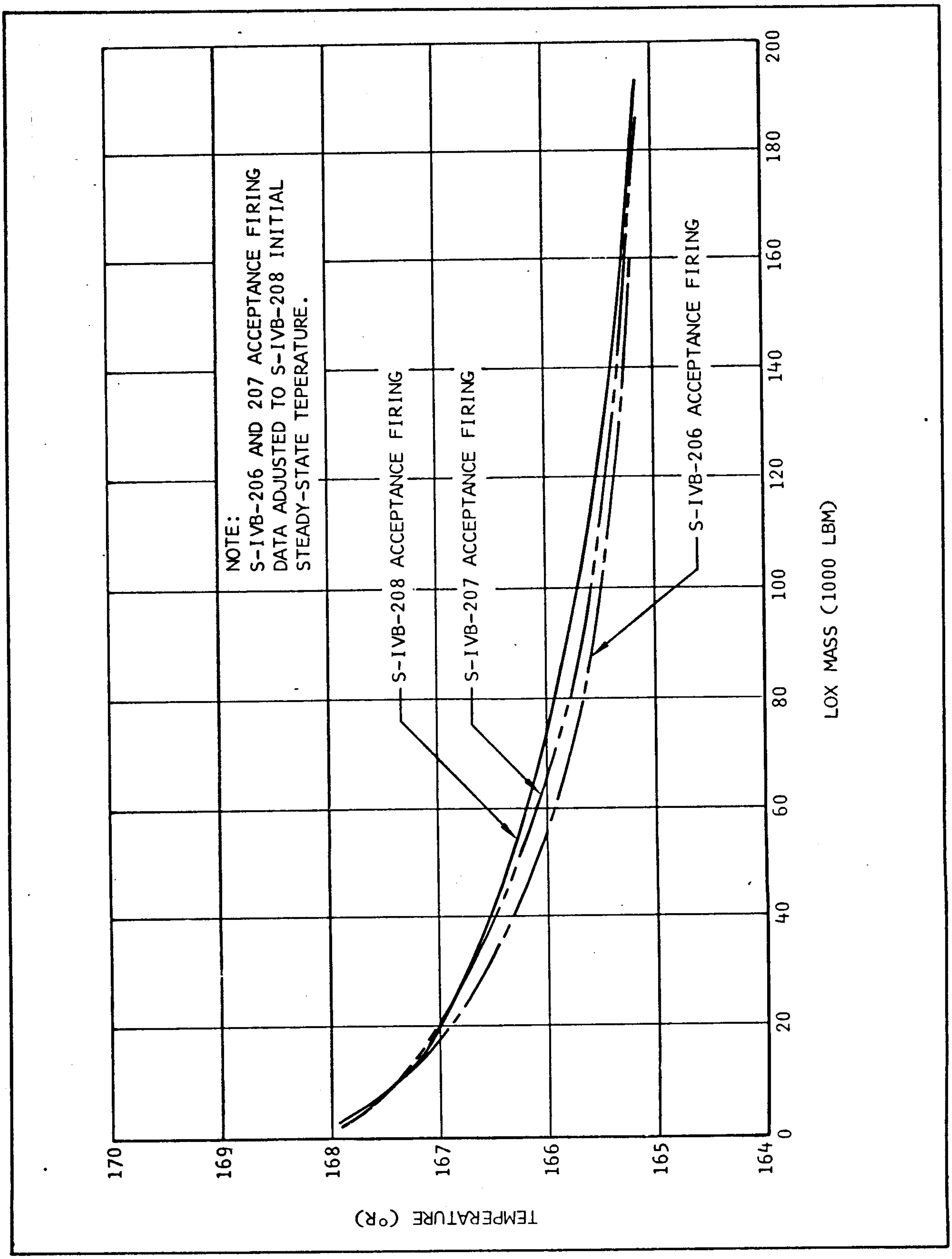

Figure 7-11. LOX Mass in Tank vs Pump Inlet Temperature

8. FUEL SYSTEM

The fuel system performed as designed and supplied LH2 to the engine within the limits defined in the engine specification, although marginal performance was noted in the pump chilldown operation.

8.1 Pressurization Control

The LH2 tank pressurization system (figure 8-1) performed adequately and satisfactorily controlled LH2 tank ullage pressure throughout the firing.

8.1.1 Prepressurization

LH2 tank helium prepressurization from GSE console "B" was satisfactory. Data are presented in figure 8-2 and compared with S-IVB-206 and -207 data in table 8-1. As a result of low supply pressure (D0778), the helium flowrate was somewhat lower than normal. This resulted in a longer than usual prepressurization duration. The helium mass used in prepressurizing the tank was somewhat lower than previously noted because of slight differences in volume and pressure switch setting, as compared with previous tests. After prepressurization was terminated, the ullage temperature increased because of ambient heat input until engine start command and resulted in the ullage pressure increase shown in the figure.

8.1.2 Pressurization

During engine operation, LH2 tank pressurization was satisfactorily accomplished by the GH2 tapoff system (figure 8-1). The data are presented in figure 8-3 and compared with data from two previous acceptance firings in table 8-2. The data indicated a performance level substantially higher than that noted on previous stages. This increased performance, i.e. flowrate, is a direct result of the uprating of the J-2 engine (J-2062) which is effective on this and subsequent stages. The steady-state fuel injector pressure of 910 psia was approximately 60 psia higher, and the fuel injector temperature at 192 deg R was 5 to 10 deg R lower than the normal levels observed on past stages. Both of these conditions contributed to the higher levels of fuel pressurization flowrate. The higher flowrate plus the narrow pressure switch control band (table 8-2) resulted in a control cycle that was of a higher frequency and shorter duration than those noted on previous stages.

The tank relief valve cracking pressure was not reached on this firing because the pressurization system had been operating on undercontrol for approximately 35 sec prior to step pressurization and the ullage pressure had decreased to a relatively low level, thus preventing step pressurization from increasing the pressure to a level that would unseat the valve.

8.2 LH2 Pump Chilldown

The fuel chilldown system performance was adequate; pump inlet conditions at engine start command were 38.1 psia and 41.4 deg R which produced an NPSH of 7.6 psi. This performance, which was similar to that observed during the S-IVB-207 stage acceptance firing, was not as good as seen in previous chilldown operations (table 8-3) because of unusually high heat inputs to the chilldown system. This heat input, however, was not as great as that during the S-IVB-207 firing and did not produce unfavorable conditions during the engine start transient. System data and the results of performance calculations are presented in figures 8-4 and 8-5 and compared with data from two previous acceptance firings in table 8-3.

The flowrate went through the usual start transient except that it decreased to 46 gpm before it increased to and stabilized at 80 gpm. After another small transient, the flowrate reached 85 gpm where it remained until prepressurization. During the steady-flow period, the pressure drop across the chilldown pump was 10 psid. The unpressurized steady-state flowrate, which was 15 gpm below normal, and the pressure drop, which was slightly higher than usual, indicate excessive vaporization in the system.

Examination of the data, during a quiescent period before recirculation was initiated, revealed that the liquid in the system was saturated at that time. Pump inlet temperature C0658, pump outlet temperature C0157, and return line temperature C0161 were biased on this basis.

The flow coefficient, which is a measure of the chilldown system flow resistance, was higher than that of previous acceptance firings. For the S-IVB-208 acceptance firing the LH2 in the system was subcooled during pressurized chilldown; unlike the saturated condition found at the return line during prepressurization of the S-IVB-207 stage acceptance firing. However, the pressurized flowrate (136 gpm), which was significantly lower than normal, led to the calculation of a relatively high flow coefficient (20 sec^2/in^2ft^3). The average flow coefficient calculated for pressurized chilldown was then used to determine the fluid quality during unpressurized chilldown. Since the pressure drop for the S-IVB-207 and -208 acceptance firings are the same and the S-IVB-208 flow coefficient is higher, the fluid quality obtained for the S-IVB-208 acceptance firing is lower than that of S-IVB-207.

Because of instrumentation limitations, the heat input resulting in LH2 vaporization in section 1 (table 8-3) during unpressurized operation could not be calculated; the 24,500 Btu/hr (table 8-3) represents sensible heat only. The heat input going into LH2 vaporization, as calculated from the fluid quality estimate, was arbitrarily assigned to sections 2 and 3 (table 8-3), although this unusually high heat input (31,000 Btu/hr) can also be attributed to condensed nitrogen on the system return line.

After prepressurization, all of the heat inputs went into heating the pressurized fluid, and no vaporization occurred because all temperatures were below saturation. The total pressurized heat input is within the range of other acceptance firings in which the helium purge was operating at 65 scfm; however, the heat input is excessive in section 1 while it is below normal in sections 2 and 3. The same general phenomenon occurred during the S-IVB-207 firing.

The cause of this heat input is being investigated; several sources are discussed in the following paragraphs:

a. The helium purge of the chilldown valve was checked after the firing, and the flow was found to be 65 scfm. A gas sample taken from within the fairing contained less than 2 percent nitrogen; there were no apparent leaks between the outside environment and the inside of the fairing. It is, therefore, doubtful that any GN2 could have condensed on the hardware if the purge operated during the acceptance firing as it did during postfiring checkout. Analysis, however, indicates that GN2 condensation on the recirculation line (including pump and shutoff valve) inside the fairing could be responsible for the high heat transfer into this section.

b. The foam insulation around the chilldown pump and valve was examined and found to be loosely installed. Any ambient heat would have penetrated the system quite freely if the purge had failed for some reason.

c. The improved GN2 purge system in the aft interstage on S-IVB-207 and -208 directed more GN2 onto the chilldown line running outside the fairing through the interstage to the feed duct. However, the vacuum jacket around the line was checked and found to be adequate, thus any heat transfer to this part of the chilldown line was negligible.

d. Since the elbow on the end of the return line at the tank inlet was not insulated for the S-IVB-207 and -208 firings, it is almost certain that GN2 would condense on this section. However, the heat input to this final section appears to be lower than usual rather than excessive.

e. The excessive heat inputs did not occur during the S-IVB-205 and -206 acceptance firings or during the special S-IVB-503 chilldown test, all of which were performed on the Beta III test stand. The problem was encountered only on S-IVB-207 and -208, which were both tested on the Beta I test stand, indicating that a facility problem may be involved. This possibility is presently being investigated.

8.3 Engine LH2 Supply

The engine LH2 supply system (figure 8-6) satisfactorily supplied LH2 to the engine pump inlet throughout engine operation and maintained the pressure and temperature within a range that provided an NPSH above the minimum requirement. The data and the results of the performance calculations are presented in figure 8-7 and compared with data from two previous acceptance firings in table 8-4.

The fuel pump inlet pressure and temperature were plotted in the engine operating region (figure 8-8) and showed that the fuel pump inlet conditions were met satisfactorily throughout the firing. Figure 8-9 is a plot of the pump inlet temperature versus the mass remaining in the LH2 tank during burn and included previous acceptance firing data for comparison. The S-IVB-208 data agreed closely with the S-IVB-206 and -207 data.

TABLE 8-1
LH2 TANK PREPRESSURIZATION

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
Prepressurization initiation (sec from T_0)	-110.1	-110.7	-109.6
Prepressurization termination (sec from T_0)	-41.6	-39.1	-32.1
Prepressurization duration (sec)	68.5	71.6	77.5
Helium mass used during prepressurization (lbm)	36.4	38.72	33.76
Ullage pressure at prepressurization termination (psia)	33.6	34.1	33.4
Ullage pressure at simulated liftoff (psia)	35.0	34.7	33.9
Ullage pressure at engine start (psia)	37.6	37.4	36.4
Ullage pressure rise rate after prepressurization (psia/min)	1.22	1.04	0.99

TABLE 8-2
LH2 TANK PRESSURIZATION

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
Number of control cycles	2	2	2
Control pressure switch range (psia)	26.8 to 29.1	27.1 to 29.3	27.3 to 29.0
Ullage pressure at engine start (psia)	37.6	37.4	36.4
Ullage pressure at step pressurization (psia)	29.1	28.5	28.2
Ullage pressure at engine cutoff (psia)	38.6	38.9	37.3
Time of step pressurization (sec from ESC)	301.1	301.3	300.2
GH2 pressurant flowrate:			
Undercontrol (lbm/sec)	0.35	0.36	0.40
Overcontrol (lbm/sec)	0.63	0.65	0.68
Step before cutback (lbm/sec)	1.12	1.10	1.18
Step after cutback (lbm/sec)	1.04	0.99	1.08
Total GH2 pressurant mass (lbm)	281.6	281.2	285.1
Time of relief valve opening (sec from ESC)	407	408	N/A
Pressure at relief valve operation (psia)	38.4	38.35	N/A
LH2 boiloff during engine operation (lbm)	0	0	0

N/A - not applicable

TABLE 8-3 (Sheet 1 of 2)
FUEL CHILLDOWN SYSTEM PERFORMANCE

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
Maximum NPSH (psia)	25.5	15.9	17.5
NPSH at Engine Start Command (psia)	18.0	6.8	7.6
Minimum NPSH required engine start (psia)	6.4	6.3	6.5
Average flow coefficient ($sec^2/in^2 ft^3$)	18.2	18.95	20.0
Fuel quality (sections 2 & 3 - unpressurized)			
Maximum (lbm gas/lbm mixture)	0.033	0.377	0.295
At prepressurization (lbm gas/lbm mixture)	0.025	0.067	0.049
Fuel pump inlet at Engine Start Command			
Static pressure (psia)	38.5	38.2	38.1
Temperature (deg R)	38.6	41.6	41.4
Heat absorption rate - unpressurized (Btu/hr)*			
Section 1	21,000	24,000†	24,500†
Sections 2 and 3	18,000	38,000	31,000
Total	39,000	62,000	55,500
Heat absorption rate - pressurized (Btu/hr)*			
Section 1	17,500	49,000	46,000
Section 2	22,000	10,000	3,000
Section 3	21,500	13,500**	14,000
Total	61,000	72,500**	63,000
Unpressurized childown flowrate (gpm)	108	85	85
Pressurized childown flowrate (gpm)	143	139	136
Unpressurized pressure drop (psia)	9.4	10	9.8
Pressurized pressure drop (psia)	8	8	8

*Section 1 is tank to pump inlet; section 2 is pump inlet to bleed valve; section 3 is bleed valve to tank.

†These values represent only the sensible heat observed in section 1. Due to instrumentation limitations, the heat input going into LH2 vaporization in section 1 cannot be calculated.

**These values represent only the sensible heat observed in section 3. Due to limitations of the method used, the heat input going into LH2 vaporization cannot be calculated.

TABLE 8-3 (Sheet 2 of 2)
FUEL CHILLDOWN SYSTEM PERFORMANCE

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
Events (sec from T_0)			
Chilldown start	-305.1	-505.6	-596.5
Prevalve closed	-301.8	-301.9	-592.7
Prepressurization	-110.1	-110.7	-109.6
Prevalve (start) open	147.22	147.86	148.6
Events (sec from T_0)			
Chilldown pump off	150.2	150.26	150
Chilldown shutoff valve closed	150.34	150.44	568.7
Engine Start Command	150.16	150.86	150.27

TABLE 8-4
LH2 PUMP INLET CONDITIONS

PARAMETER	S-IVB-206	S-IVB-207	S-IVB-208
Pump inlet conditions at engine start			
Static pressure (psia)	38.5	38.2	38.1
Temperature (deg R)	38.6	41.6	41.4
NPSH requirements			
At high EMR (psi)	5.8	5.8	6.5
After EMR cutback (psi)	5.6	5.6	5.9
NPSH available			
At Engine Start Command (psi)	18.0	6.8	7.6
At Engine Cutoff Command (psi)	10.2	16	16
Minimum NPSH (psi) and time of occurrence (sec from ESC)	9.5 245	9.5 270	9.5 215
Suction duct			
At high EMR			
Pressure drop (psi)	0.5	0.5	0.5
Flowrate (lbm/sec)	82.1	80.5	85.5
After EMR cutback			
Pressure drop (psi)	0.5	0.3	0.5
Flowrate (lbm/sec)	77.0	74.2	79.4

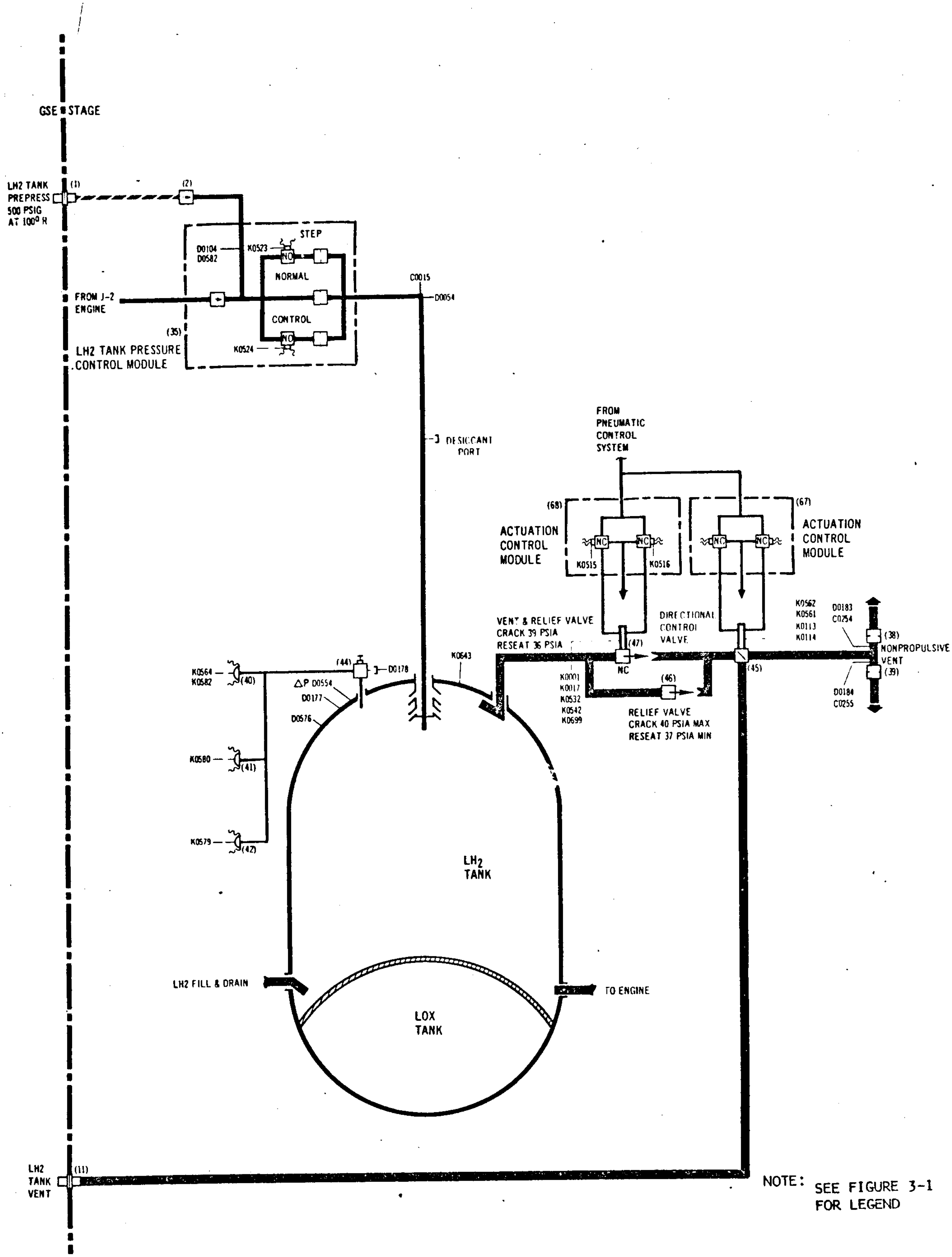

Figure 8-1. LH2 Tank Pressurization System

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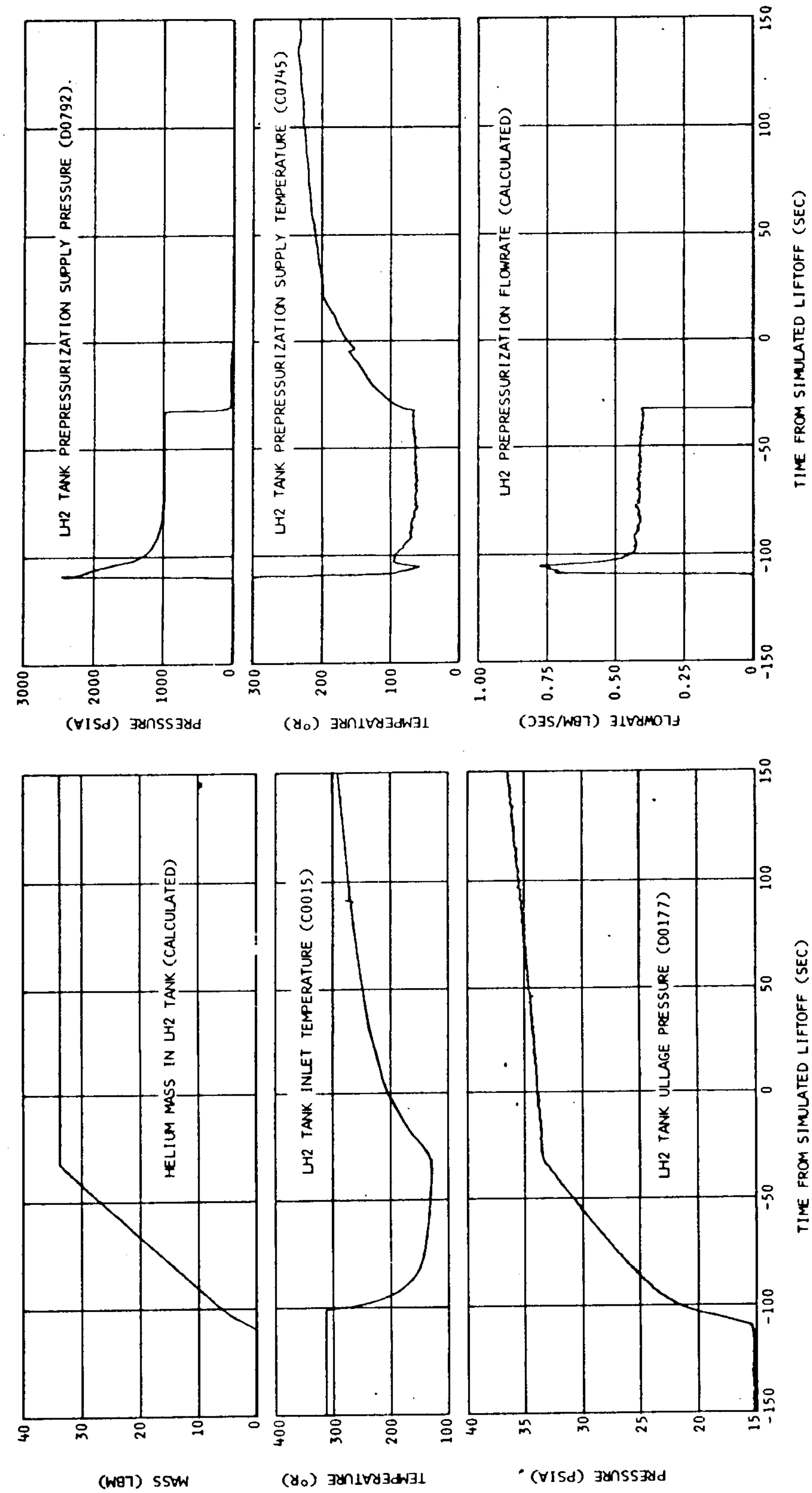

Figure 8-2. LH2 Tank Prepressurization System Performance

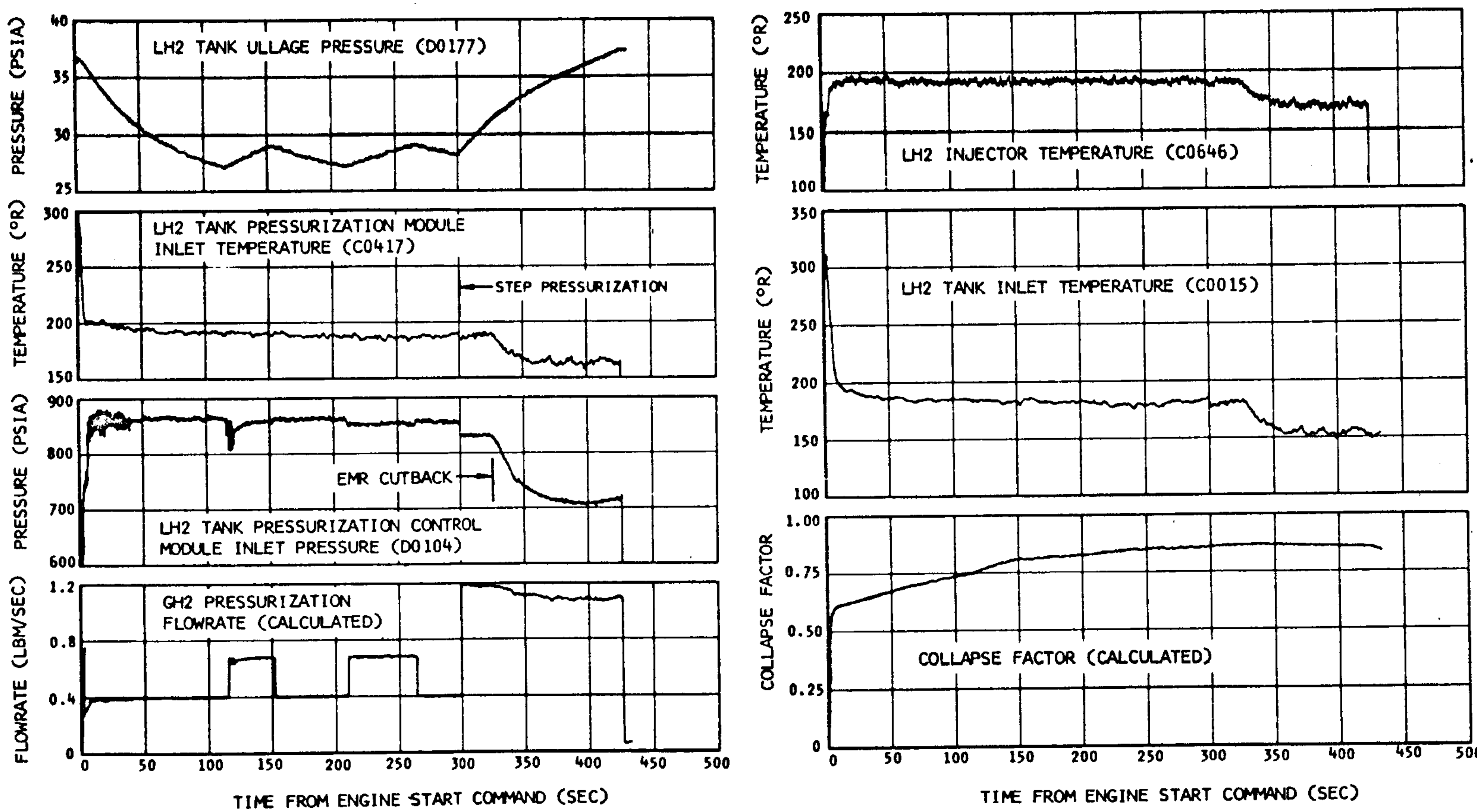

Figure 8-3. LH2 Tank Pressurization System Performance

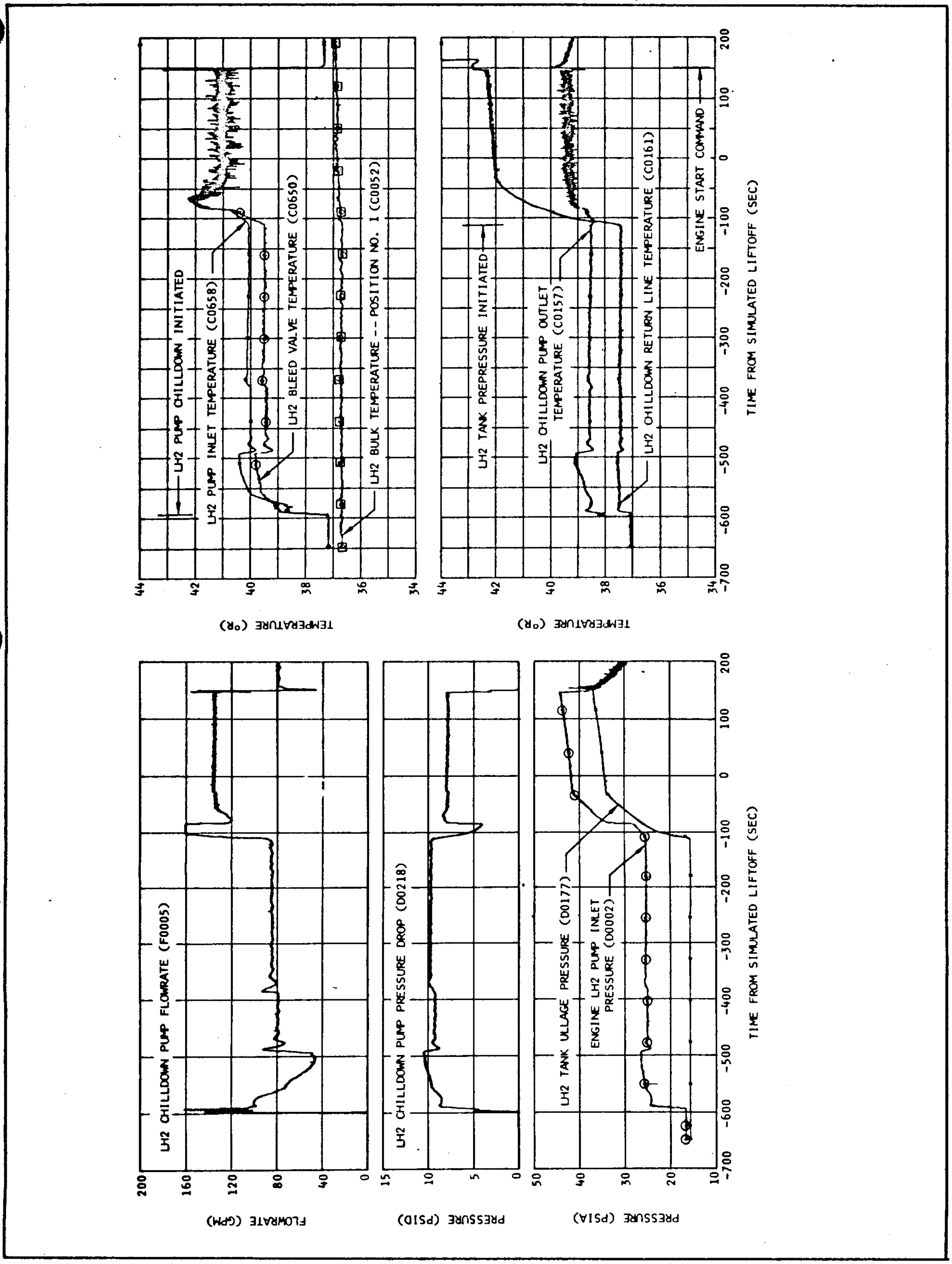

Figure 8-4. LH2 Pump Childown

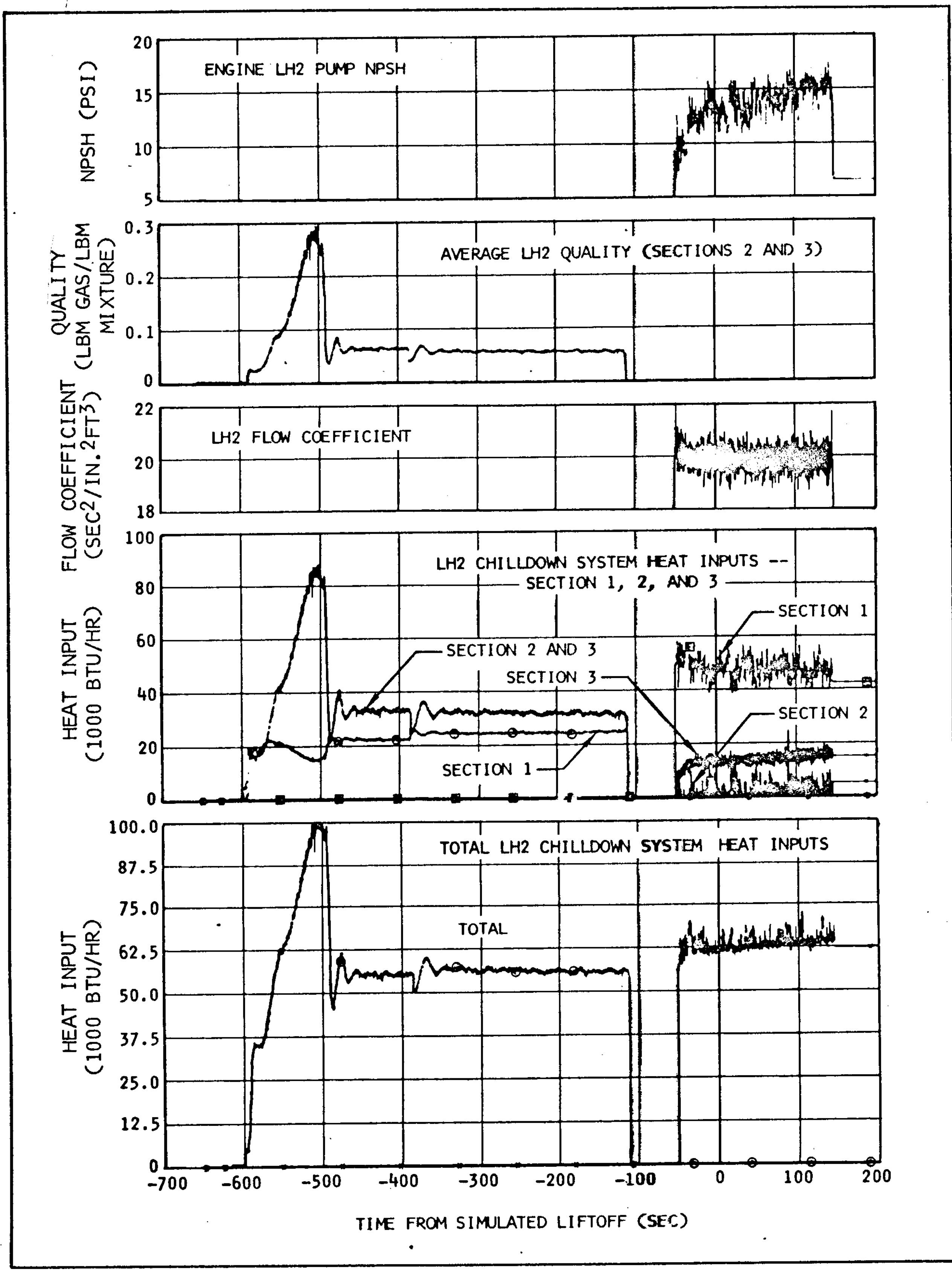

Figure 8-5. LH2 Pump Chilldown Characteristics

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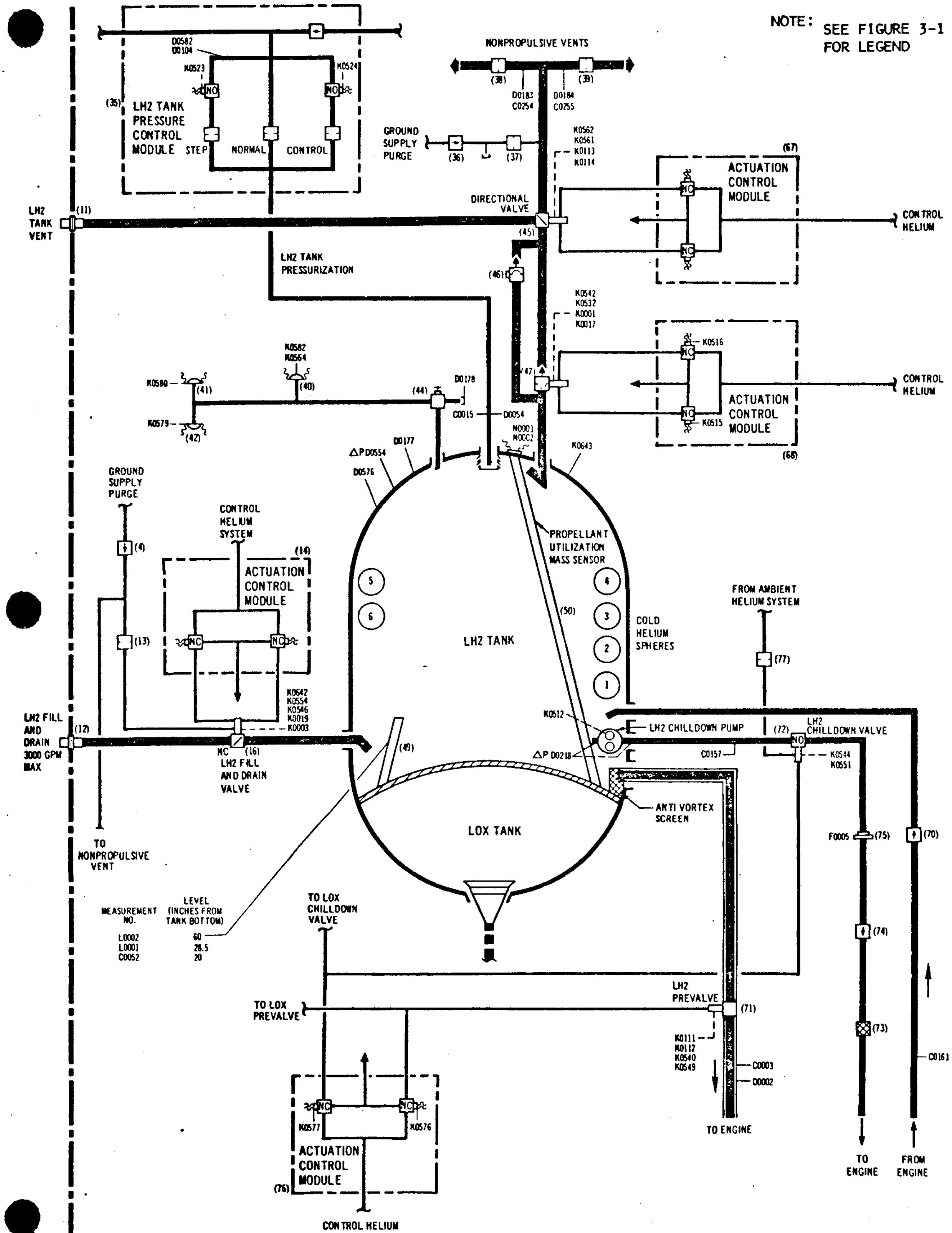

Figure 8-6. LH2 Supply System

27 March 1967

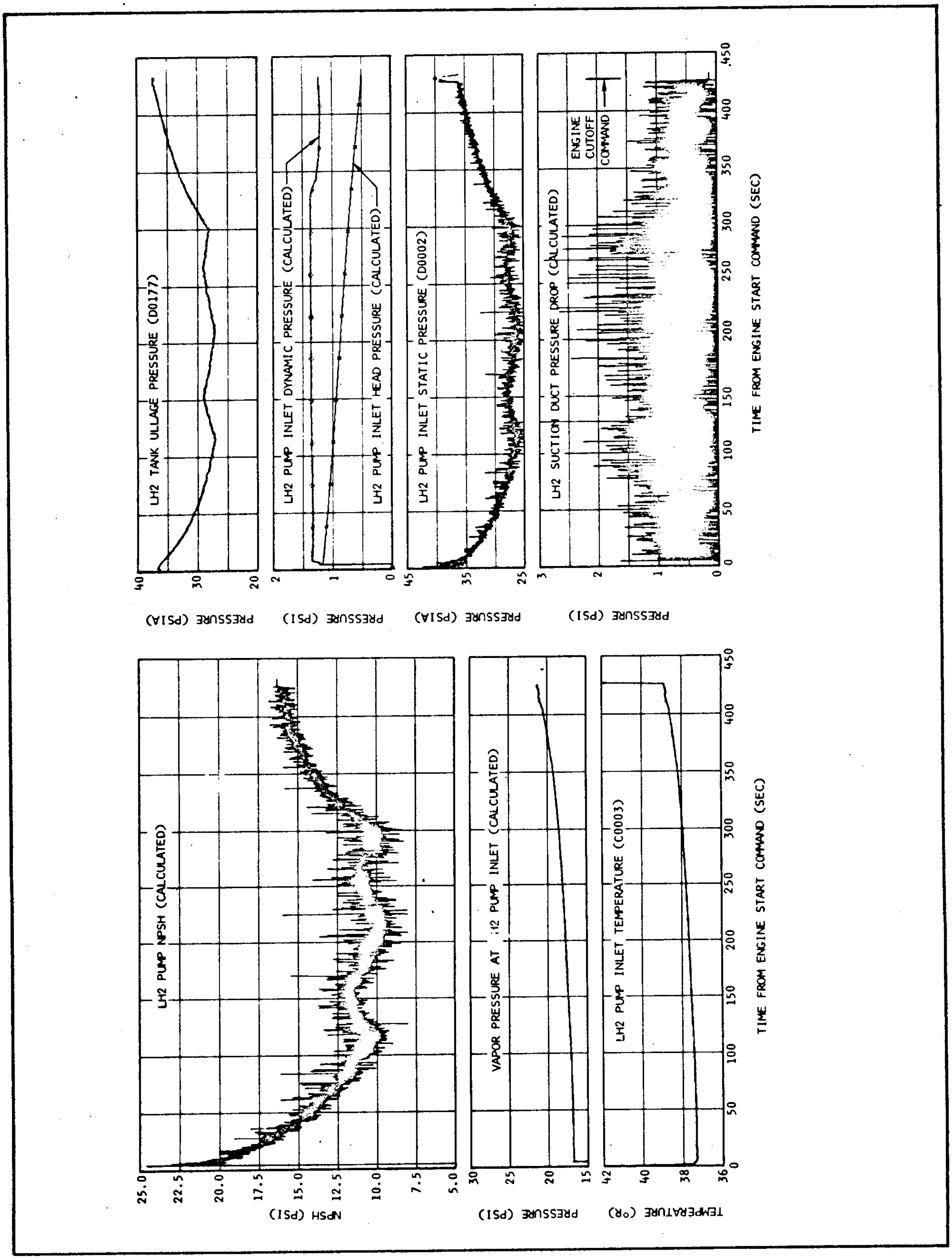

Figure 8-7. LH2 Pump Inlet Conditions

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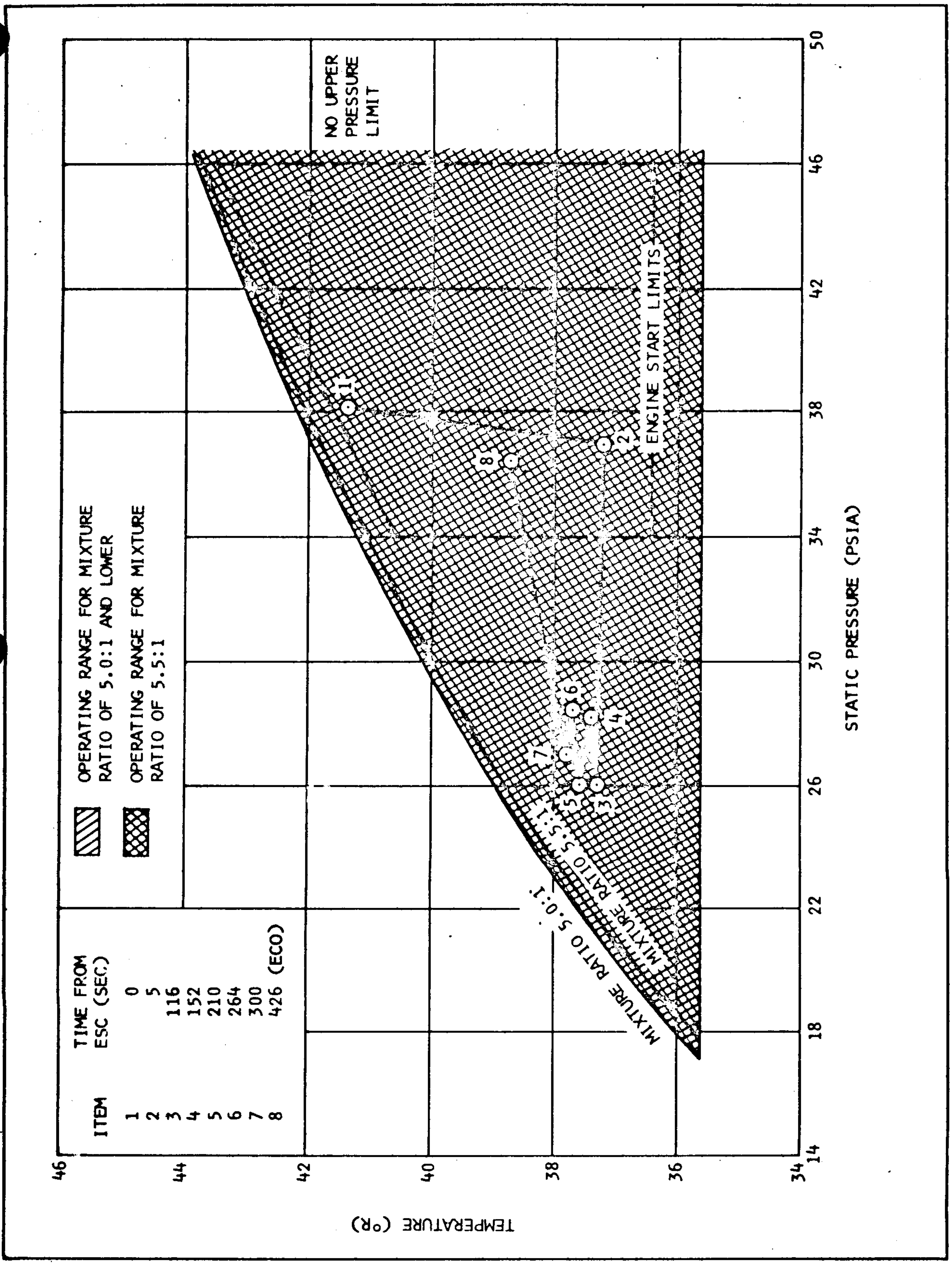

Figure 8-8. LH2 Pump Inlet Conditions During Firing

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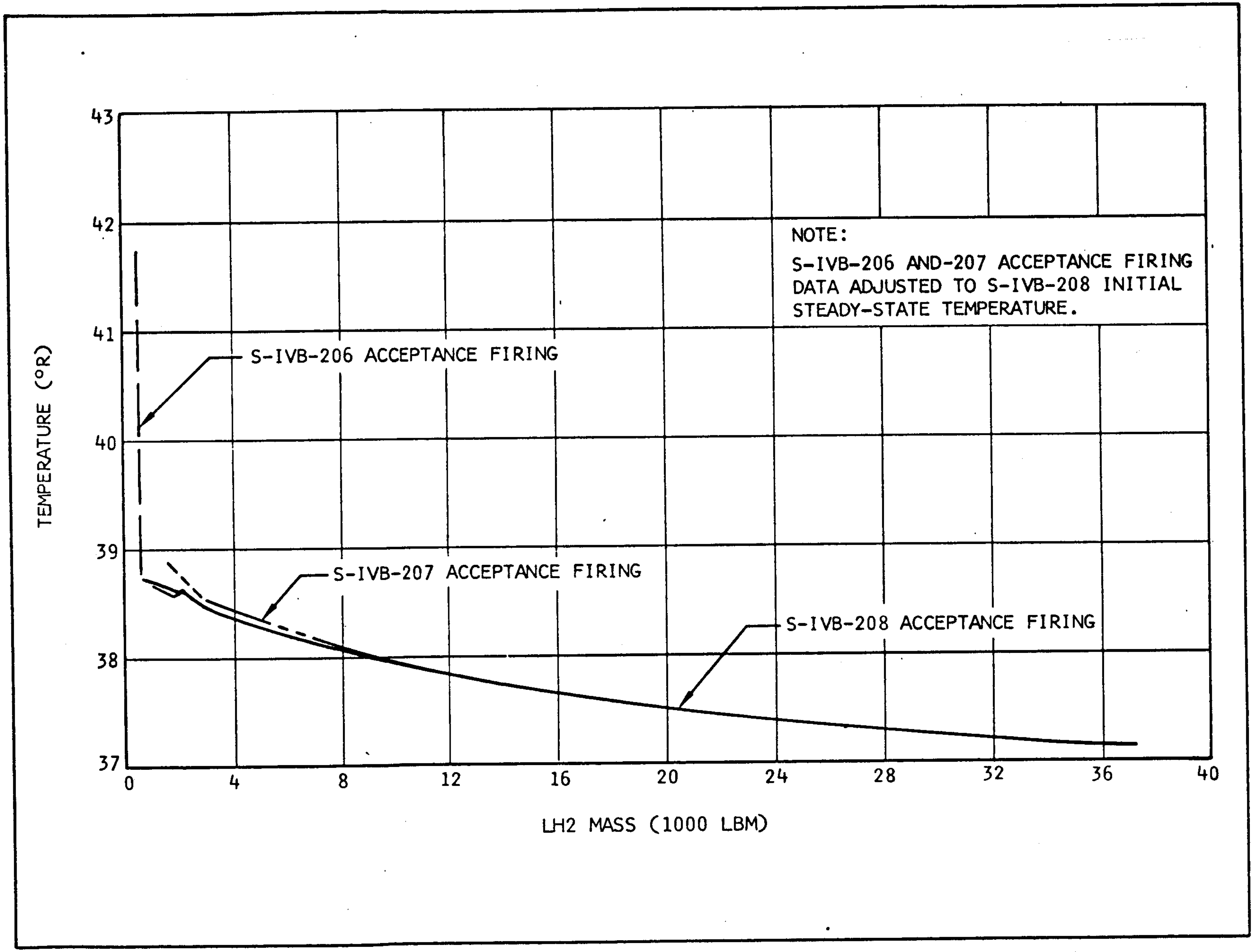

Figure 8-9. LH2 Mass in Tank vs Pump Inlet Temperature

9. PNEUMATIC CONTROL AND PURGE SYSTEM

The pneumatic control and purge system (figure 9-1) performed satisfactorily throughout the acceptance firing. The helium supply to the system was adequate for both pneumatic valve control and purging; the regulated pressure was maintained within acceptable limits and all components functioned normally. The temperature transducer for this system was removed before the acceptance firing; therefore, mass and temperature data cannot be presented. The data that were obtained are presented in figure 9-2 and are compared with data from two previous acceptance firings in table 9-1.

9.1 Pneumatic Control

All engine and stage pneumatic control valves responded properly throughout the countdown and acceptance firing. The pneumatic control helium regulator operated satisfactorily.

9.2 Ambient Helium Purges

During the acceptance firing, 10 purge functions were satisfactorily accomplished. The pneumatic system was isolated from ground support equipment at T_0 +90 sec; therefore, the purges from the facility were discontinued at this time. The purge function characteristics are listed in table 3-2.

Throughout the acceptance firing, the LOX chilldown motor container purge pressure was maintained within the design range. This demonstrated satisfactory operation of the ambient helium purge system.

The data trend appears normal but the stabilization pressure during chilldown pump operation is higher than seen during previous tests. This abnormality is presently under investigation.

TABLE 9-1
PNEUMATIC CONTROL AND PURGE SYSTEM DATA SUMMARY

PARAMETERS	S-IVB-208	S-IVB-207	S-IVB-206
<u>Sphere Conditions</u>			
Pressure at simulated liftoff (psia)	2970	3005	3150
Pressure at T_0 +90 sec* (psia)	2946	3010	3135
Pressure at Engine Start Command (psia)	2935	2989	3090
Pressure at Engine Cutoff Command (psia)	2930	2985	3010
Temperature at simulated liftoff (deg R)	**	480	523
Temperature at T_0 +90 sec* (deg R)	**	480	520
Temperature at Engine Start Command (deg R)	**	480	517
Temperature at Engine Cutoff Command (deg R)	**	487	511
Mass at T_0 +90 sec* (lbm)	**	1.10	1.166
Mass at Engine Cutoff Command (lbm)	**	1.07	1.143
Mass usage from T_0 +90 sec* until prevalves opened (lbm)	**	0.005	0.006
Mass usage during interval required to close LOX and LH2 chilldown shutoff valves (lbm)	**	0.025	0.017
Mass usage during engine operation (lbm)	**	0	0
Total mass usage from T_0 +90 sec * to Engine Cutoff Command (lbm)	**	0.03	0.023
<u>Regulator Outlet</u>			
Maintained output pressure (psia)	540-510	540-510	545-520
System pressure drop during start and cutoff transients (psid)	445	445	470
<u>LOX Chilldown Motor Container Purge</u>			
Purge pressure range	49-52***	49-52***	40***

*GSE was isolated at T_0 +90 sec.

**Temperature and mass data are not available for S-IVB-208 stage because the temperature transducer was removed before the acceptance firing.

***Pressure switch range was 37 to 40 psia for S-IVB-206; it was 49 to 53 psia for S-IVB-207 and -208.

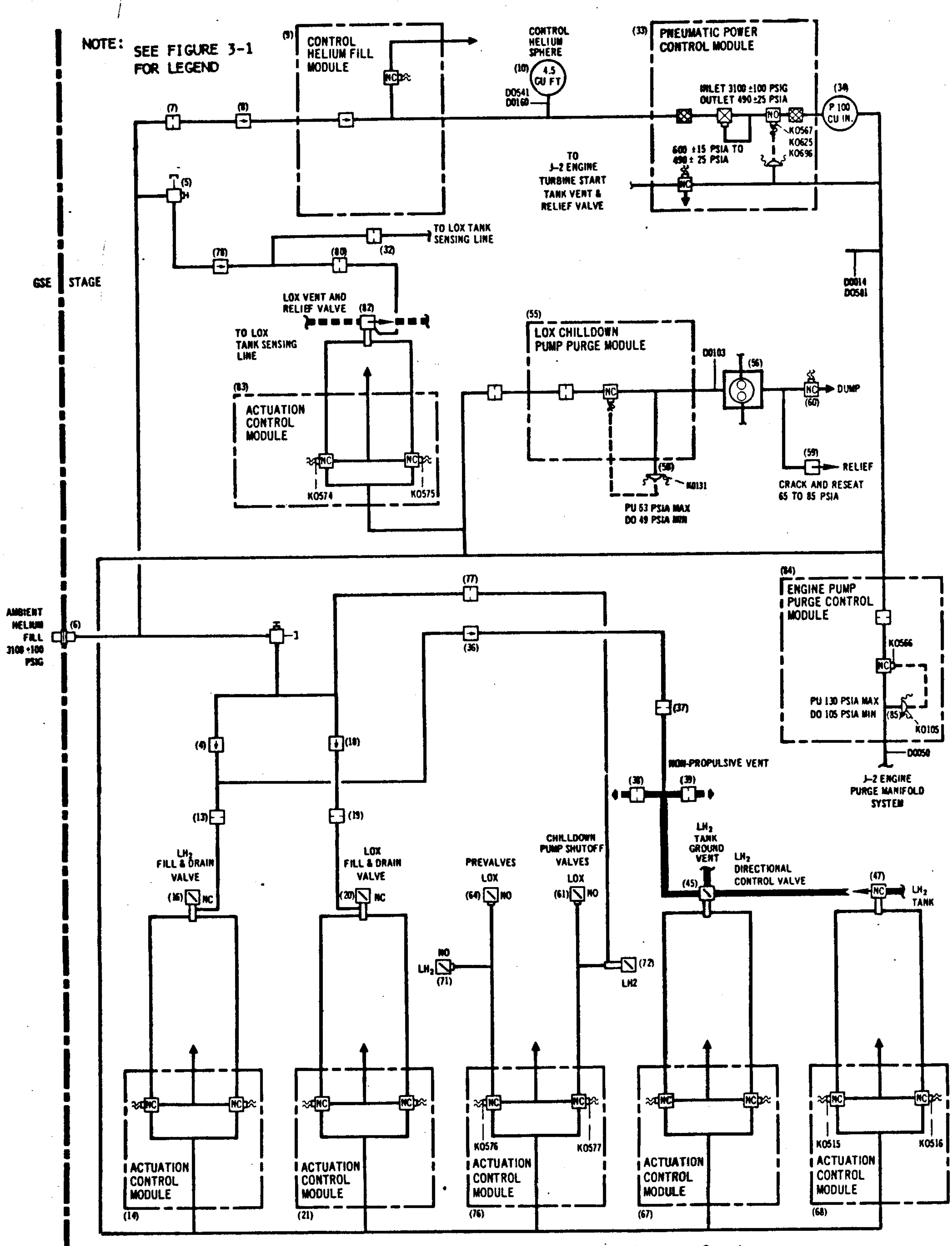

Figure 9-1. Pneumatic Control and Purge System

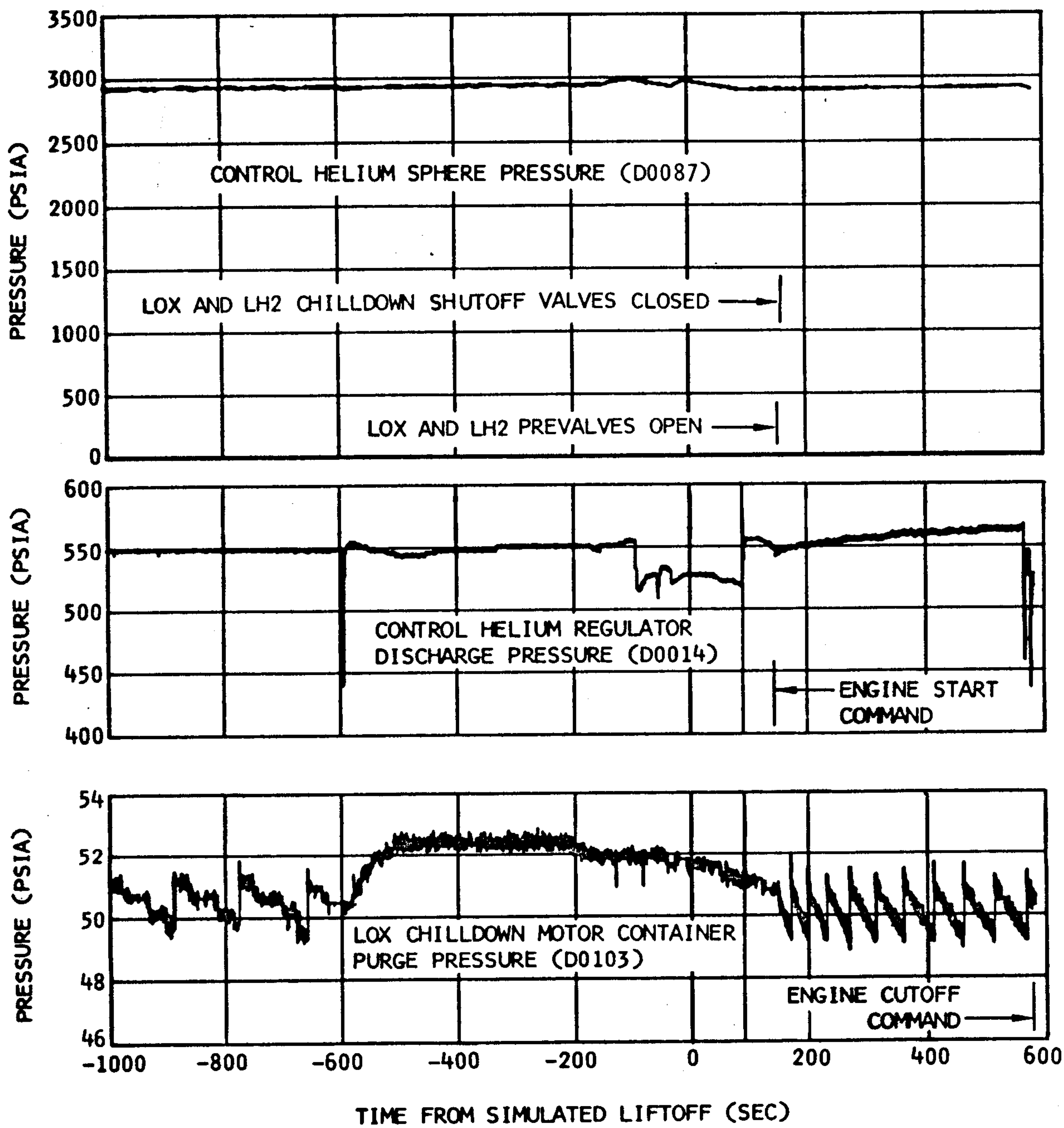

Figure 9-2. Pneumatic Control and Purge System Performance

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10. PROPELLANT UTILIZATION SYSTEM

The propellant utilization (PU) system accomplished all design objectives as listed in Douglas Report No. SM-47458, *Saturn S-IVB-208 Stage Acceptance Firing Test Plan.*

The S-IVB-208 acceptance firing was the second test of the PU system redesigned slosh filter and the reshaped LOX sensor. PU system operation with these modifications was satisfactory throughout burn with PU valve cutback occurring at Engine Start Command (ESC) +303 sec. The predicted valve cutback time was ESC +280 sec. Flow integral results show that the LOX tank-to-sensor mismatch was reduced by the redesigned LOX sensor. The reduced LOX tank-to-sensor mismatch combined with the LH2 tank-to-sensor mismatch resulted in a PU valve and thrust tail-up during the last 30 sec of burn. The +3.5 deg valve tail-up resulted in a 2,700 lbf thrust increase.

Final loaded PU indicated mass is more within 0.56 and 0.71 percent of actual LOX and LH2 masses, respectively.

10.1 PU System Calibration

The nominal pre-acceptance mass sensor calibration was determined from a combination of empirical and theoretical analysis.

The propellant mass at the lower calibration point was determined from the calculated unique tank volume and predicted propellant density. The corresponding capacitance was determined from vendor's sensor calibration data and fast drain data from previous acceptance firings.

The LOX propellant mass and its corresponding capacitance at the upper calibration point was determined from the vendor's calibration data and the immersed LOX sensor data from the S-IVB-207 stage. The LH2 propellant mass and its corresponding capacitance at the upper calibration point was determined from the vendor's calibration data and sensor data from the S-IVB-501 and -502 stages. The LOX and LH2 PU mass sensor calibrations are listed in the following table:

PU MASS SENSOR	CAPACITANCE (pf)	MASS (lbm)	LOCATION
LOX	281.54	1,339	Bottom of inner element
	413.08	196,396	Top of inner element
	410.97	193,273	Full load
LH2	972.02	211	Bottom of inner element
	1,188.44	44,981	Top of inner element
	1,151.53	37,346	Full load

10.2 Propellant Utilization

10.2.1 Propellant Loading

The following is a tabulation of the desired, indicated, and actual full propellant loading at (T_0) for the S-IVB-208 stage acceptance firing:

PROPELLANT LOADING	LOX (lbm)	LH2 (lbm)
Desired full load (predicted)	193,273	37,346
Indicated full load (PU reading)	193,550	37,364
Actual full load (flow integral)	192,481	37,102
Difference (indicated less desired)	277	18
Difference (actual less desired)	-892	-244
Difference (indicated less actual)	1,069	262

10.2.2 Propellant Mass History

Propellant mass history during the stage acceptance firing is presented in table 10-1. Results of the flow integral and volumetric methods of mass determination will be used to calibrate the PU system capacitance mass sensors to achieve the desired 1 percent stage loading accuracy for flight.

Flow integral mass values shown in table 10-1 were based on the analysis of engine flowmeter data, and thrust chamber pressure differential. Residual mass values at engine cutoff were based on best estimate residual data.

The flow integral method consists of determining the mass flowrate of LOX and LH2 and integrating as a function of time to obtain total consumed mass during firing. The initial full-loaded mass on board is determined by adding the following items to the total consumed mass:

DESCRIPTION	LOX (lbm)	LH2 (lbm)
Propellant residual	1,587	1,013
Net mass lost through boiloff	140	
GH2 pressurant used		285
TOTAL	1,727	1,298

10.2.3 Propellant Residuals

Propellant residual masses were computed at engine cutoff command using both level sensors and the PU mass sensor. One LH2 level sensor (L0002) and two LOX level sensors (L0004 and L0005) were used for this purpose.

Propellant residuals from level sensors are derived by subtracting the propellant consumption between level sensor activation and engine cutoff command from the propellant mass at level sensor activation. The propellant consumption data were obtained from engine flow data.

The best estimate residuals are at engine cutoff generated by the level sensor and PU mass sensor data.

The following table presents a comparison of propellant residuals.

LEVEL SENSOR RESIDUAL AT ENGINE CUTOFF		
	LOX (lbm)	LH2 (lbm)
L005	1,778	
L004	1,476	
L002		962
Statistical average	1,558 $\pm$225	962 $\pm$61

STAGE RESIDUAL AT ENGINE CUTOFF		
	LOX (lbm)	LH2 (lbm)
Level Sensor Statistical Average	1,558 ±225	962 ±61
PU System	1,646 ±320	1,090 ±75
Stage Residual Best Estimate	1,587 ±184	1,013 ±47

10.3 System Operation

10.3.1 PU System Response

Figures 10-1 and 10-2 indicate the normalized nonlinearity of the LOX and LH2 mass sensor as compared to the flow-integral reference. If a smooth curve were drawn through these graphs, it would represent the mass sensor-to-tank mismatch. The LOX mass sensor has a maximum error of approximately 0.34 percent occurring near the 40 percent level of the tank. The LH2 mass sensor has a maximum error of approximately 0.39 percent, near the 12 percent level of the tank. Superimposed on these hypothetically smooth mismatch nonlinearity curves are the manufacturing-produced discontinuities in the linearity.

PU system valve cutback occurred at ESC +303 sec. The predicted valve cutback time was ESC +280 sec. The PU system response with the new slosh filter was as expected during the cutback transient. The actual mean level of valve position after the cutback transient was approximately 3.5 deg higher than predicted. The major difference between the actual and the predicted PU valve response was caused by the difference between actual and predicted J-2 engine environment and tank-to-sensor mismatch. The following table summarizes the deviations between the actual and predicted valve position histories.

DESCRIPTION	CUTBACK TIME DEVIATION (sec)	VALVE POSITION SHIFT (deg)
1. Engine performance shift	0	-0.5
2. Open loop flowrate deviation	15.0	1.0
3. Loading deviations	2.3	0
4. PA49 Mass/capacitance calibration deviations	0.5	0
5. Difference between predicted and actual PA49 tank-to-sensor mismatch nonlinearities	5.0	2.5
Total	22.8	3.0

Considering the above factors, the predicted cutback time would increase by 22.8 sec and the mean level of valve position after cutback would increase by 3.0 deg. This gives a close comparison between the actual valve response and the postfiring reconstruction (shown in figure 10-3).

The thrust variations during the last 70 sec of burn exceeded the MSFC thrust requirements (table 6-6). Figure 6-14 shows the thrust history of the last 70 sec of burn. The mean slope during the last 70 sec was -60 lbf/sec and the maximum deviation from this mean slope was 2,200 lbf. The deviation of the predicted mean from the actual mean at ESC -70 sec was 5,000 lbf. The maximum slope during the last 70 sec was -440 lbf/sec. There was a thrust tail-up of 2,700 lbf during the last 30 sec due primarily to the actual tank-to sensor mismatch and the J-2 engine environment. The last 10 sec of the cutback transient occurred during the last 70 sec of burn due to the shorter engine burn (described in section 6) and the later (23 sec) than nominal predicted PU valve cutback.

At ESC +342 sec, an engine performance shift occurred which caused the LOX and LH2 flowrates to be higher than predicted (section 6). The performance shift had no effect on the PU valve cutback time, but did result in a change in the valve level by -0.5 deg in the last 70 sec. The valve position history difference was obtained by comparing the actual results with a simulation that did not include the engine performance shift.

The effect of the differences between the predicted and actual pump inlet conditions, pressurization rates, boiloff rates, and engine tag values for the S-IVB-208 acceptance firing was to increase cutback time by 15.0 sec and to shift the mean level of valve position after cutback by +1.0 deg.

Loading deviations are the differences between the PU system indicated loads at engine start command and the desired PU system indicated loads at engine start command. The loading deviations were +331 lbm LOX and +38 lbm LH2. The combined effect of these loading deviations increased cutback time by 2.3 sec. The mean level of the valve position after cutback is not affected by these loading deviations.

Calibration deviations at engine start command were 0.599 percent LOX and 0.812 percent LH2 thus causing the initial masses to be over loaded by the above percentages. Calibration deviations at engine cutoff command were 0.262 percent LOX and 0.505 percent LH2. The slope deviations between engine start command and engine cutoff command 0.339 percent LOX and 0.319 percent LH2. These slope deviations did not significantly affect the desired bridge gain ratio (BGR) of 4.8:1.0. The LOX equivalent calibration error between the mass/capacitance end points was +0.02 percent. This LOX equivalent calibration deviation caused a 0.5 sec increase in cutback time and a 0 deg shift in valve position.

The effect of the differences between the average of previous acceptance test tank-to-sensor mismatch results used for the S-IVB-208 prediction and the actual S-IVB-208 acceptance tank-to-sensor mismatch increased cutback time by +5.0 sec and shifted the mean value of valve position by +3.0 deg.

Figures 10-5 and 10-6 show the predicted and actual mismatch extended to the sensor extremities with the sensor manufacturing nonlinearities removed. The LH2 mismatch error tail-off that occurred between a LH2 tank mass of 8,000 lbm and cutoff, was the primary cause for the PU valve tail-up during the last 30 sec of burn. The S-IVB-208 LOX tank-to-sensor mismatch was reduced by the LOX sensor reshape. The shape and magnitude of the LOX and LH2 tank-to-sensor mismatch error curves obtained from the S-IVB-207 and -208 acceptance tests are approximately the same.

10.3.2 PU Efficiency

The closed-loop PU efficiency was found to be 99.99 percent based on the extrapolation to depletion of all usable propellants. Using engine consumption rates at cutoff, extrapolation resulted in a total usable residual of 26.2 lbm LH2. The propellant consumption flowrates at engine cutoff were 79.53 lbm/sec of LH2 and 383.73 lbm/sec of LOX and represent the summation of the total flow through the engine, the boiloff rates, and the GH2 pressurant flowrate at that time.

TABLE 10-1
PROPELLANT MASS HISTORY

EVENT	FLOW INTEGRAL MASS (lbm)			PU SYSTEM (1) MASS (lbm)			DEVIATION (2) (lbm)	
	LOX	LH2	TOTAL	LOX	LH2	TOTAL	LOX	LH2
Simulated Liftoff (T_0)	192,481	37,102	229,583	193,207	37,234	230,441	726	132
Engine Start Command (ESC) (3) T_0 +150.270	192,481	37,102	229,583	193,207	37,234	230,441	726	132
PÛ Valve Cutback ESC +303.02	51,977	11,217	63,194	52,503	11,280	58,162	526	63
Engine Cutoff Command (ECC) ESC +576.872	1,587	1,013	2,600	1,646	1,090	2,736	59	77

(1) = The total mass in tank as determined by the PU system (corrected for nonlinearity).

(2) = Deviation of the corrected PU system mass from the flow integral mass.

(3) = The masses shown at ESC are considered the same as the masses at T_0.

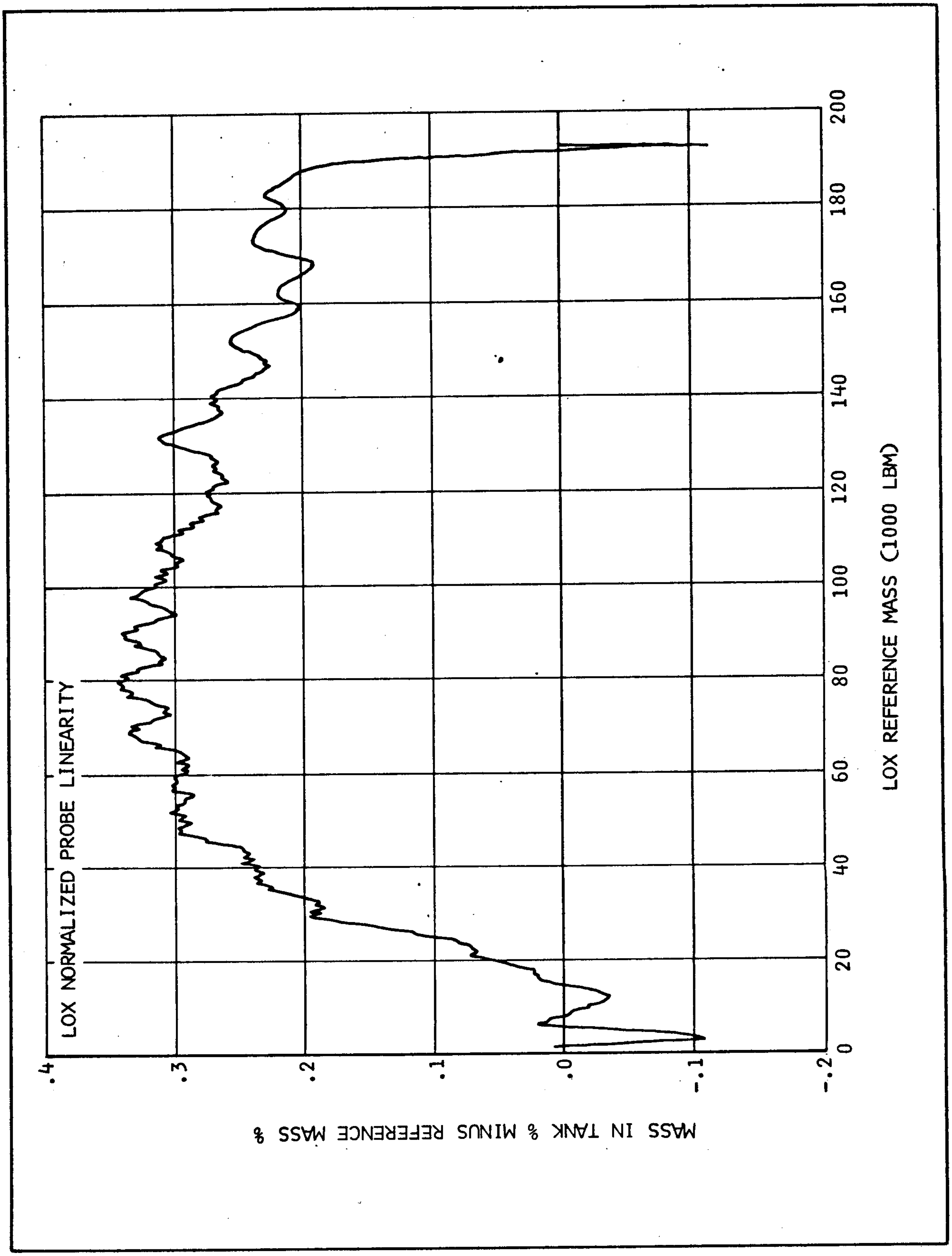


Figure 10-1. Total LOX Nonlinearity

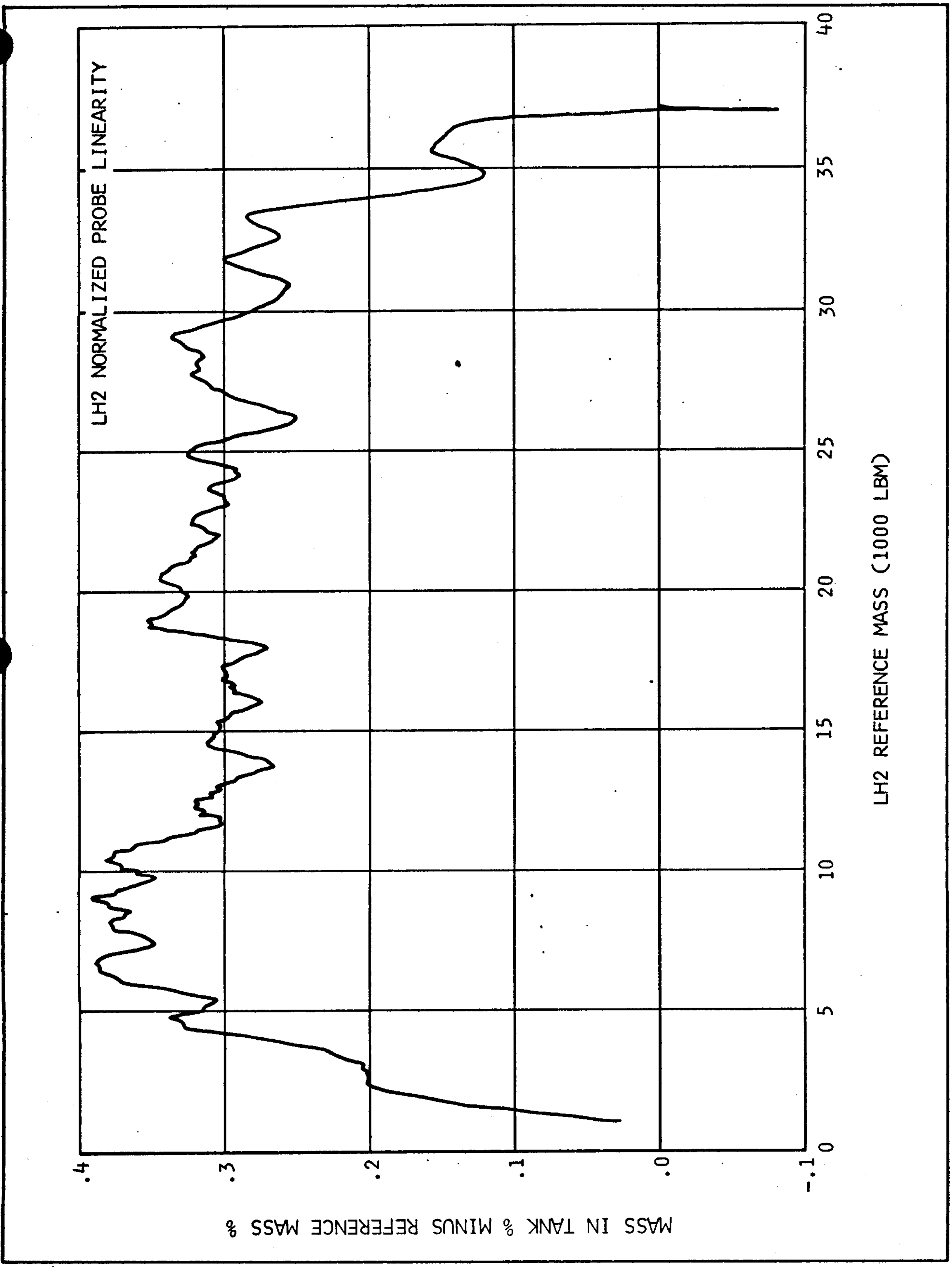


Figure 10-2. Total LH2 Nonlinearity

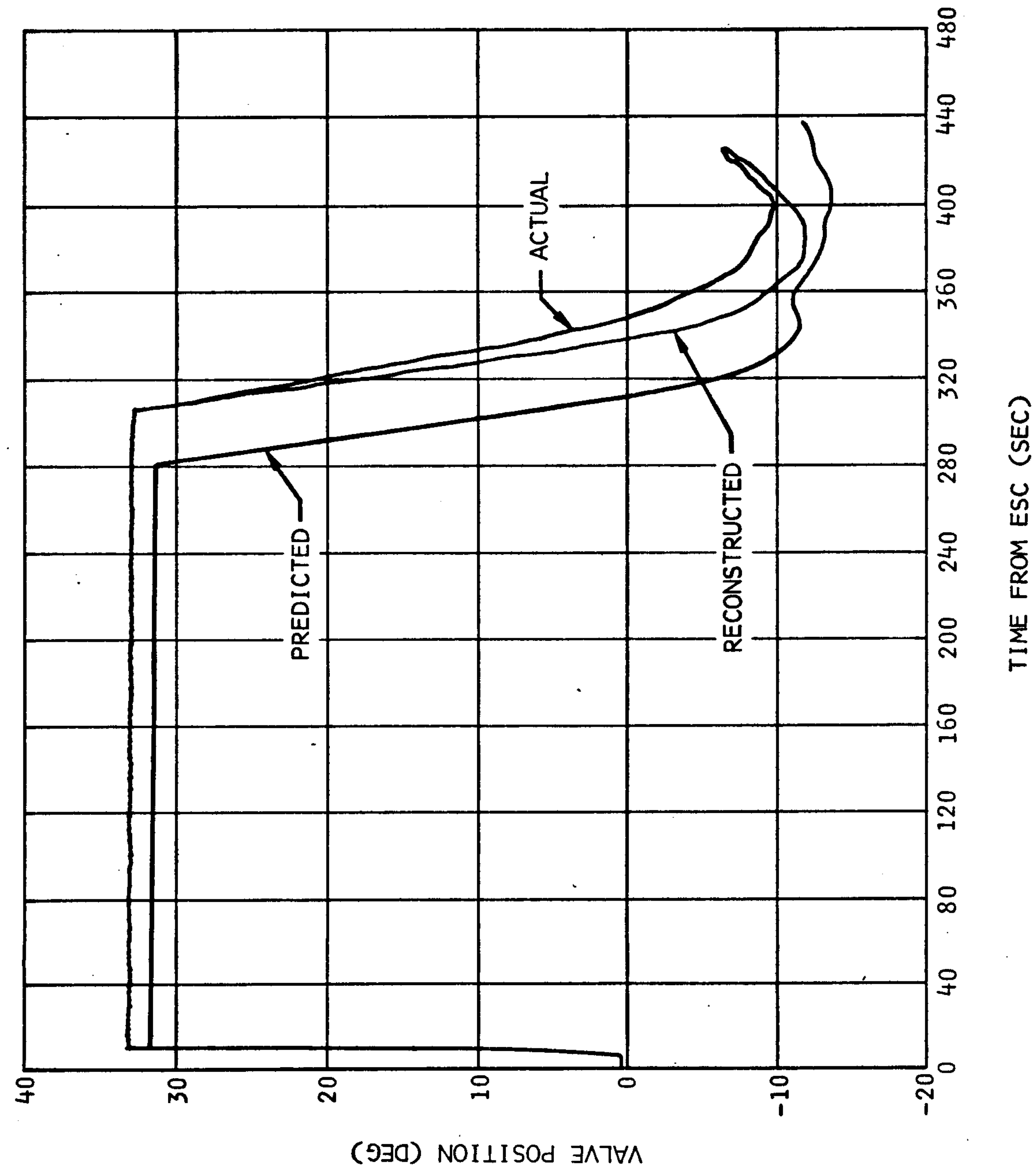


Figure 10-3. PU Valve Position

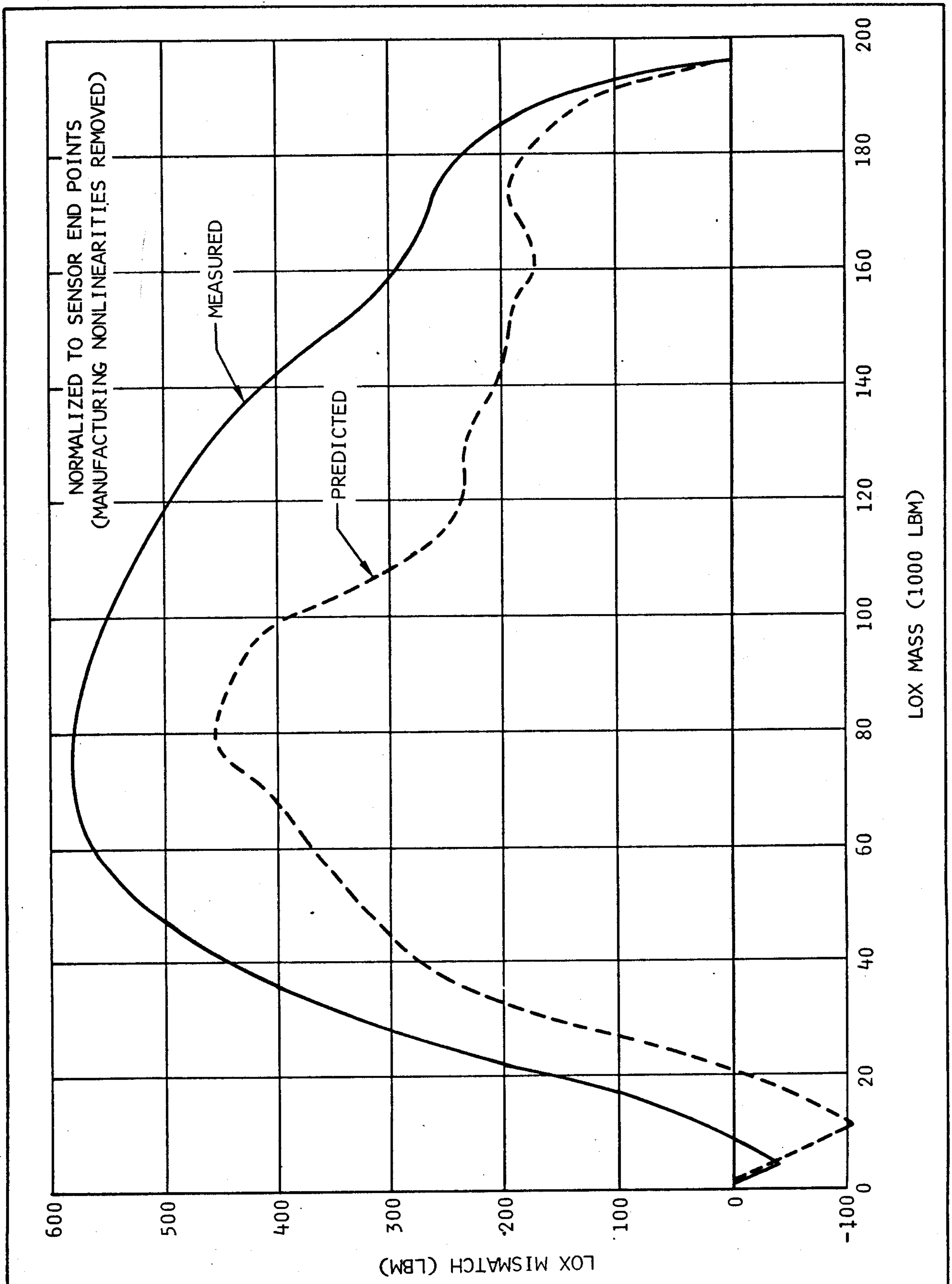


Figure 10-4. LOX Tank-to-Sensor Mismatch

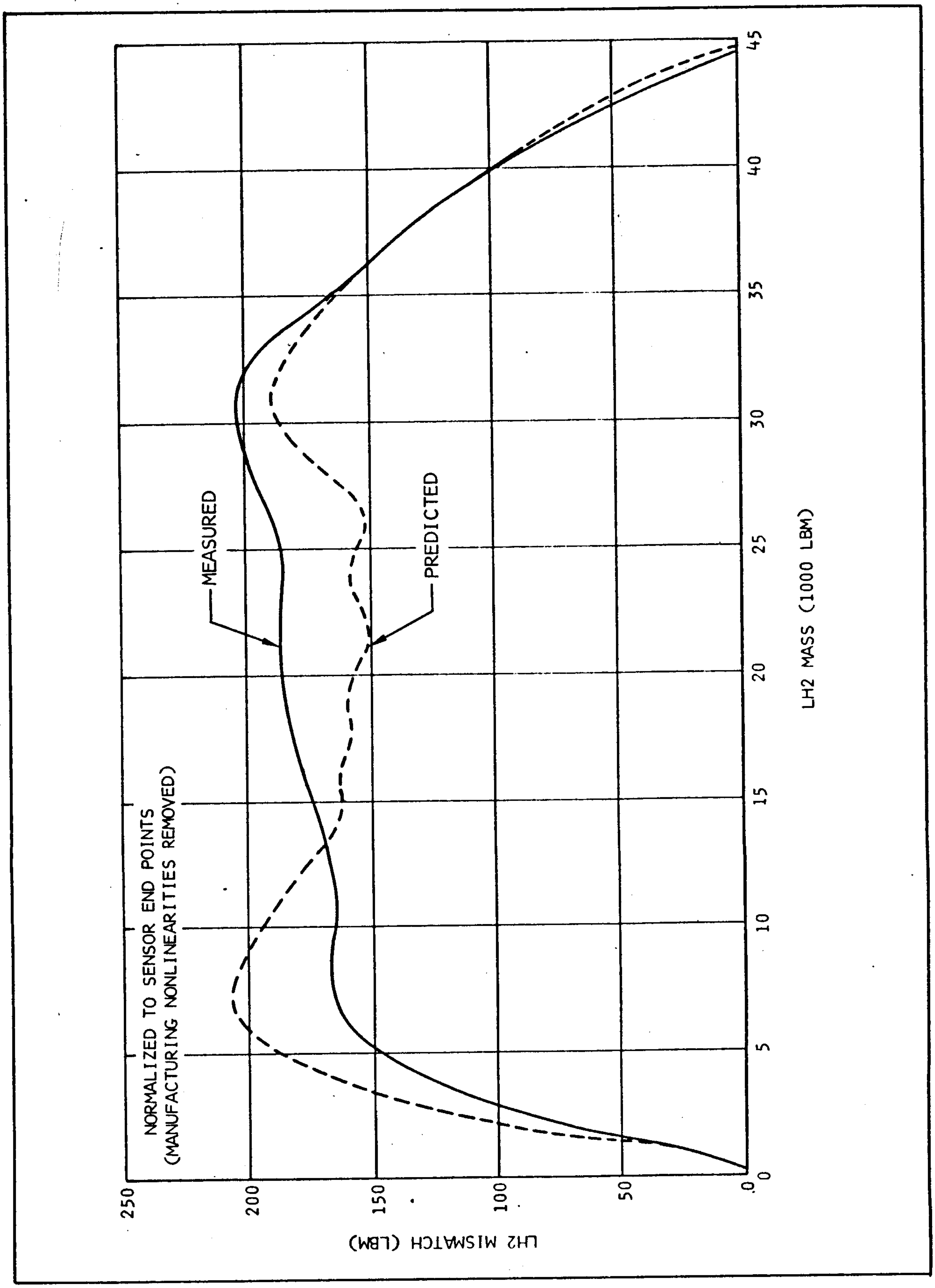


Figure 10-5. LH2 Tank-to-Sensor Mismatch

11. DATA ACQUISITION SYSTEM

The data acquisition system performed as designed by demonstrating the competency of acquiring stage information, conditioning the data signals, translating these signals into proper telemetry format, and transmitting the telemetry information to a ground station. The measurements which comprise this system are specified in Douglas Drawing No. 1B43561L, *Instrumentation Program and Components List (IP&CL)*. A measurement summary is presented in the following table:

Measurement Efficiency	99.4%
Total number of measurements designed	232
Total number of measurements deleted	55
Total number of active measurements	177
Measurement failures	1
Total successful measurements	176

The data acquisition system satisfactorily accomplished its acceptance firing criterion as specified by the *Stage Acceptance Firing Test Plan* (SM 47458, as amended). The system performed as expected; no system malfunction was observed and the system was free of radio frequency interference and was electromagnetically compatible with other stage systems.

11.1 Instrumentation Subsystem Performance

The instrumentation system performed satisfactorily throughout the acceptance firing. The system performance is presented in table 11-1. The status of the inactive measurements is tabulated in table 11-2.

Ten measurement problems were observed during the acceptance firing. These discrepancies that occurred are listed, with their qualification comments in table 11-3.

One measurement failed during the firing, C0001 [Temperature-LH2 Turbine Inlet, Gas Generator (GG) Gas].

Measurement C0134 (Temperature-LH2 Pump Discharge) indicated a data offset due to uncompensated calibration.

Measurement D0009 (Pressure-LOX Pump Discharge) shifted calibration.

Measurements D0183 and D0184 (LH2 Tank Non-Prop. Vent 1 and 2 Pressures) were susceptible to the radio frequency (RF) environment. These are strain gage type transducers which were known for these undesirable indications.

Multiplexer problems were encountered on measurements M0030 [Range Safety (R/S), F/U 1 Exploding Bridgewire (EBW) Voltage] and N0003 (PU System, LH2 Fine Mass Indication).

Chilldown inverter noise (EMC problem) was observed on measurements D0104 (LH2 Pressure Module Inlet Pressure), M0006 and M0007 (Engine Control and Ignition Buses), and M0069 [Aft Telemetry (T/M) Full Scale Reference Voltage].

The remote analog checkout system (RACS) calibration at T_0 -3,044 sec (1119:02 PST) verified that all measurements were within acceptable tolerance except those mentioned above.

The comparison of pulse code modulation (PCM) and hardwire, table 11-4 [strip chart, ground instrumentation system (GIS), frequency modulation (fm)] data was satisfactory. Confidence in the T/M data has been verified.

11.2 Telemetry Subsystem Performance

The telemetry system performance was good. No loss of system synchronization was observed. Good data were received from all channels. Digital data acquisition system (DDAS) to T/M comparison did not reveal any difference in data.

Inflight 270 multiplexer calibration was observed at T_0 -3,045, T_0 +93, and T_0 +628 sec. Calibration was verified on all channels.

11.3 RF Subsystem Performance

The RF system performed well within system specifications. Acceptable signal strength was observed at the ground station.

The nominal RF assembly power output was 18.3 watts. The voltage standing wave ratio (VSWR) was 1.60:1.

11.4 Electromagnetic Compatibility

Interference from other stage systems was not observed. However, several transducers exhibited electromagnetic susceptibility. These were mentioned previously under paragraph 11.1.

11.5 Emergency Detection System Measurements

The LH2 and LOX tank ullage emergency detection system (EDS) pressure measurements performed satisfactorily. The variation between the LOX EDS measurements, which is within instrumentation tolerance, was introduced in the data reduction process.

11.6 Hardwire Data Acquisition System Performance

The ground instrumentation system (GIS) provides a backup and data comparison for certain stage telemetry system parameters in addition to recording measurements from the ground support and facility equipment. The GIS also provides strip charts for redline and cutoff parameter monitoring. The GIS performance during the acceptance firing was satisfactory.

The following table presents the type of recording equipment and the number of channels used during the acceptance firing.

Ground Recorder	Channels Assigned
Beckman 210 Digital Data System	234
Constant Bandwidth FM	61
Wideband FM	6
Strip Charts	28
Total	329

Table 11-5 presents a tabulation of the various types of measurement data recorded and the performance of the system.

11.6.1 Hardwire

There was one measurement failure and one measurement was classified partially successful yielding an overall hardwire efficiency of 99.65 percent. Measurement discrepancies that occurred during the acceptance firing are listed in table 11-6.

TABLE 11-1
INSTRUMENTATION SYSTEM PERFORMANCE SUMMARY

FUNCTION	NUMBER ASSIGNED PER IP&CL	INACTIVE	ACTIVE	FAILED	DISCREPANCIES
Acceleration	0	-	-	-	-
Acoustic	0	-	-	-	-
Temperature	45	13	32	1	1
Pressure	58	24	34	0	4
Vibration	0	-	-	-	-
Flow	4	0	4	0	0
Position	8	5	3	0	0
Events	68	8	60	0	0
Liquid Level	5	1	4	0	0
Volt/Current/Freq	29	0	29	0	4
Miscellaneous	13	4	9	0	1
Strain	0	-	-	-	-
Speed	2	0	2	0	0
Total	232	55	177	1	10

TABLE 11-2 (Sheet 1 of 4)
T/M MEASUREMENT STATUS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
VXC0007-401	DP1B0-17L05	Temp - Engine Control Helium	Open - S/C 1195A requirement for T/M disconnect and H/W recording
VC0050-401	CP1B0-11-03 DP1B0-11-03	Temp - Hyd Pump Inlet Oil	Open - T/M disconnect Douglas requirement for H/W recording and redline cutoff
C0102-411	DP1B0-02-05	Temp - Fwd Battery No. 1	Simulated heat sink - primary batteries not used for acceptance firing
C0103-411	DP1B0-02-06	Temp - Fwd Battery No. 2	Same as C0102-411
C0104-404	DP1B0-11-10	Temp - Aft Battery No. 1	Same as C0102-411
C0105-404	DP1B0-14-10	Temp - Aft Battery No. 2	Same as C0102-411
C0166-414	DP1B0-20L01	Temp - He Sphere Gas Mod 1 (APS)	Simulated - APS not installed for acceptance firing
C0167-415	DP1B0-20L02	Temp - He Sphere Gas Mod 2 (APS)	Same as C0166-414
XC0168-414	CP1B0-11-04 DP1B0-11-04	Temp - Oxid Tank Outlet Mod 1 (APS)	Same as C0166-414
XC0169-415	CP1B0-11-05 DP1B0-11-05	Temp - Oxid Tank Outlet Mod 2 (APS)	Same as C0166-414
XC0170-414	CP1B0-11-06 DP1B0-11-06	Temp - Fuel Tank Outlet Mod 1 (APS)	Same as C0166-414
XC0171-415	CP1B0-11-07 DP1B0-11-07	Temp - Fuel Tank Outlet Mod 2 (APS)	Same as C0166-414
C0200-401	DP1B0-18L06	Temp - Fuel Injection	Open - S/C 1195A requirement for T/M disconnect and H/W recording
VXD0041-403	CP1B0-13-05 DP1B0-13-05	Press - Hydraulic System	Same as C0200-401
VXD0042-403	DP1B0-06-07	Press - Reservoir Oil	Same as C0200-401

TABLE 11-2 (Sheet 2 of 4)
T/M MEASUREMENT STATUS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
VXD0063-414	DP1B0-07-02	Press - Fuel Supply Manifold Mod 1 (APS)	Simulated - APS not installed for acceptance firing
VXD0064-414	CP1B0-13-07 DP1B0-13-07	Press - He Regulator Inlet Mod 1 (APS)	Same as VXD0063-414
VD0065-414	CP1B0-13-08 DP1B0-13-08	Press - He Regulator Outlet Mod 1 (APS)	Same as VXD0063-414
VXD0066-415	DP1B0-13-03	Press - Oxid Supply Manifold Mod 2 (APS)	Same as VXD0063-414
VXD0067-415	DP1B0-07-04	Press - Fuel Supply Manifold Mod 2 (APS)	Same as VXD0063-414
VXD0068-415	CP1B0-13-09 DP1B0-13-09	Press - He Regulator Inlet Mod 2 (APS)	Same as VXD0063-414
VD0069-415	CP1B0-13-10 DP1B0-13-10	Press - He Regulator Outlet Mod 2 (APS)	Same as VXD0063-414
VXD0078-414	CP1B0-17	Press - Attitude Control Chamber 1-1	Same as VXD0063-414
VXD0079-414	CP1B0-18	Press - Attitude Control Chamber 1-2	Same as VXD0063-414
VXD0080-414	CP1B0-19	Press - Attitude Control Chamber 1-3	Same as VXD0063-414
VXD0081-415	CP1B0-20	Press - Attitude Control Chamber 2-1	Same as VXD0063-414
VXD0082-415	CP1B0-21	Press - Attitude Control Chamber 2-2	Same as VXD0063-414
VXD0083-415	CP1B0-22	Press - Attitude Control Chamber 2-3	Same as VXD0063-414
VXD0084-414	DP1B0-07-05	Press - Oxid Supply Manifold Mod 1 (APS)	Same as VXD0063-414

TABLE 11-2 (Sheet 3 of 4)
T/M MEASUREMENT STATUS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
VXD0089-414	DP1B0-07-07	Press - Fuel Tank Ullage Mod 1 (APS)	Same as VXD0063-414
VXD0090-414	DP1B0-07-08	Press - Oxid Tank Ullage Mod 2 (APS)	Same as VXD0063-414
VXD0091-415	DP1B0-07-09	Press - Fuel Tank Ullage Mod 2 (APS)	Same as VXD0063-414
VXD0092-415	DP1B0-07-10	Press - Oxid Tank Ullage Mod 2 (APS)	Same as VXD0063-414
D0093-414	DP1B0-08-01	Press - Fuel Tank Outlet Mod 1 (APS)	Same as VXD0063-414
D0094-414	DP1B0-08-02	Press - Oxid Tank Outlet Mod 1 (APS)	Same as VXD0063-414
D0095-415	DP1B0-08-03	Press - Oxid Tank Outlet Mod 2 (APS)	Same as VXD0063-414
D0096-415	DP1B0-08-04	Press - Fuel Tank Outlet Mod 2 (APS)	Same as VXD0063-414
G0003-401	CP1B0-23-03 DP1B0-23-03	Position Main LOX Valve	Simulated - S/C 1195A requirement for T/M disconnect and hardwire record
G0004-401	CP1B0-23-04 DP1B0-23-04	Position Main LH2 Valve	Same as G0003-401
G0005-401	DP1B0-08-09	Position Gas Generator Valve	Same as G0003-401
G0008-401	CP1B0-23-05 DP1B0-23-05	Position LOX Turbine Bypass Valve	Same as G0003-401
G0009-401	DP1B0-08-10	Position GH2 Start Tank Valve	Same as G0003-401
K0020-401	CP1B0-09R01N10	Event ASI LOX Valves OPEN	Open - Switched from T/M to computer for stage control by Flight Measurement Enable Command

TABLE 11-2 (Sheet 4 of 4)
T/M MEASUREMENT STATUS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
K0116-401	CP1B0-09R02N10	Event Gas Generator Valve Closed	Same as K0020-401
K0119-401	CP1B0-09R03N06	Event Main LH2 Valve Closed	Same as K0020-401
K0121-401	CP1B0-09R03N08	Event - Main LOX Valve Closed	Same as K0020-401
K0123-401	CP1B0-09R03N10	Event - Start Tank Discharge Valve	Same as K0020-401
K0126-401	CP1B0-09R04N01 DP1B0-09-04Y01	Event - LOX Bleed Valve Closed	Same as K0020-401
K0127-401	CP1B0-09R04N02 DP1B0-09-04Y02	Event - LH2 Bleed Valve Closed	Same as K0020-401
K0128-404	DP1B0-22	Event Switch Selector	Same as K0020-401
VXL0007-403	CP1B0-11-08 DP1B0-11-08	Level - Reservoir Oil	Simulated - S/C 1195A requirement for T/M disconnect, hardwire recording, and redline
VXN0037-414	CP1B0-23-07 DP1B0-23-07	Misc - Quantity Oxid Tank Mod 1 (APS)	Simulated - APS not installed for acceptance firing
VXN0038-415	CP1B0-23-08 DP1B0-23-08	Misc - Quantity Oxid Tank Mod 2 (APS)	Same as VXN0037-414
VXN0039-414	CP1B0-23-09 DP1B0-23-10	Misc - Quantity Fuel Tank Mod 1 (APS)	Same as VXN0037-414
VXN0040-415	CP1B0-23-10 DP1B0-23-10	Misc - Quantity Fuel Tank Mod 2 (APS)	Same as VXN0037-414

TABLE 11-3 (Sheet 1 of 2)
T/M MEASUREMENT DISCREPANCIES

MEASUREMENT NO.	PARAMETER	REMARKS
C0001-401	Temp-LH2 Turbine Inlet, GG Gas	The transducer failed in the open circuit mode at T_0 +150 sec. Rocketdyne expected the malfunction to occur on these later J-2 engines. The probe is in the process of redesign.
C0134-401	Temp-LH2 Pump Discharge	The T/M to H/W comparison indicated a difference of 2 percent. Investigation of the discrepancy revealed the H/W measurement was compensated for the sensor line resistance by the calibration program (CAT-1) whereas the T/M measurement was not. This resulted in a higher than nominal temperature indication of the T/M measurement. Due to the low probe resistance and the narrow resistance range, the line resistance influences the resistance versus temperature calibration. The CAT-1 program will be changed to compensate for the line resistance.
D0009-401	Press-LOX Pump Discharge	The measurement was classified as "trend." The data and the RACS levels appeared approximately 2 percent low. The H/W to T/M comparison also indicated a difference of 2 percent. Investigation indicated the high and low RACS levels were 1.5 percent and 1.75 percent below nominal respectively; however, the digital count of the transducer output voltage indicated the correct voltage levels. It appears perhaps the sensor output level shifted, or the original calibration was not of sufficient accuracy for the measurement. The transducer was rejected and will be replaced. The transducer was furnished with the Rocketdyne J-2 engine.
D0183-409 D0184-409	Press-LH2 Tank Non-Prop Vent 1 Press-LH2 Tank Non-Prop Vent 2	These measurements experienced RF interference that resulted in the shift in data level. Vent 1 ambient pressure was 2.2 percent low; however, its RACS levels were 1.8 percent and 3.3 percent high respectively. These transducers (strain gage type) were known to be susceptible to high RF energy. As the offset is not expected in the flight environment, no action will be taken to remedy this problem on this stage.

TABLE 11-3 (Sheet 2 of 2)
T/M MEASUREMENT DISCREPANCIES

MEASUREMENT NO.	PARAMETER	REMARKS
M0030-411	Volt-R/S, F/U 1, EBW	The measurement indicated higher than the specified voltage level. The voltage level was 4.62 V when it should have been 4.2 V ±0.3 V. The apparent excessive voltage level was caused by an unusually high input impedance of Channel 04-05 of the "D" 270 multiplexer. The loss of the nominal input impedance caused an unloading of the monitoring circuit, thus increasing the output voltage level. The input logic card was replaced. Subsequent to the replacement, proper operation of the multiplexer has been verified. The multiplexer card was tested for malfunction analysis; however, the malfunction was not duplicated. The multiplexer card will not be reinstalled into the stage.
N0003-411	Miscellaneous-Volts, PU System, LOX Case Mass	Data on Channel CP1B0-03-03 failed to indicate any information; however, the redundant data Channel DP1B0-03-03 conveyed valid information. The malfunction was due to a non-operational multiplex gate; the multiplexer card has been replaced. Proper operation has been verified after the replacement. Since the malfunction was discovered prior to the acceptance firing, the absence of the CP1B0 channel was not detrimental to the acceptance firing countdown. The multiplexer card was tested for malfunction verification; however, the malfunction could not be duplicated. This problem might be peculiar to the CP1B0 multiplexer on this stage. The multiplexer card will not be reinstalled into the stage.

TABLE 11-4 (Sheet 1 of 2)
TELEMETRY TO HARDWIRE DATA COMPARISON (T_0 +213 sec)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Temp - LH2 Pump Inlet	C3	37.2	C658	37.2	37.1	37.0
Temp - LOX Pump Inlet	C4	165.5	C659	165.3	165.0	165.3
Temp - GH2 Start Bottle	C6	198	C649	204	215	--
Temp - Electrical Control Assembly	C11	509	C657	506	--	--
Temp - LOX Tank He Inlet	C16	505	C662	500	--	--
Temp - LOX Pump Discharge	C133	170.0	C648	169.9	--	169.4
Temp - LH2 Pump Discharge	C134	52.1	C644	51.6	--	51.0
Temp - Thrust Chamber Jacket	C199	142	C645	145	146	--
Temp - Cold He Sphere No. 4	C210	35.0	C661	34.3	33.6	--
Press - Thrust Chamber	D1	804	D524	805	804	--
Press - LH2 Pump Inlet	D2	29.7	D536	28.7	29.7	29.0
Press - LOX Pump Inlet	D3	40.8	D537	39.7	39.7	38
Press - Main LH2 Injector	D4	907	D518	914	--	895
Press - LH2 Pump Discharge	D8	1,258	D516	1,279	--	1,280
Press - LOX Pump Discharge	D9	1,098	D522	1,130	--	1,160
Press - GG Chamber	D10	705	D530	717	--	700
Press - Cont He Reg Discharge	D14	551	D581	566	566	570
Press - Cold He Sphere	D16*	1,378	D542	2,080	2,080	--
Press - GH2 Start Bottle	D17	1,227	D525	1,225	1,214	1,230
Press - Engine Reg Outlet	D18	414	D535	413	415	--
Press - Cont He Supply	D19	2,490	D534	2,511	2,510	--
Press - He (Amb) Sphere	D160	2,901	D541	2,920	2,895	--
Press - LOX Tank Ullage - EDS 1	D177	29.5	D539	30.0	30.7	--
Press - LOX Tank Ullage - EDS 2	D178	30.2	D539	30.0	30.7	--
Press - LH2 Tank Ullage - EDS 1	D179	38.4	D540	38.5	38.5	--
Press - LH2 Tank Ullage - EDS 2	D180	38.4	D540	38.5	38.5	--
Press - Common Bulkhead Int	D208	0.0	D545	-0.1	0.0	--
Flowrate - LOX	F1	2,990	F506	2,961	--	2,969
Flowrate - LH2	F2	8,209	F507	8,101	--	8,164

*Exhibited RFI

TABLE 11-4 (Sheet 2 of 2)
TELEMETRY TO HARDWIRE DATA COMPARISON (T_0 +213 sec)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
*Position - Pitch Actuator	G1	0.2	G504	--	0.05	0.2
*Position - Yaw Actuator	G2	0.0	G505	--	-0.02	0.15
Position - PU Valve	G10	0.17	G503	0.17	0.15	0.15
Voltage - Engine Control Bus	M6	29.1	M514	28.7	28.8	28.8
Voltage - Engine Ignition Bus	M7	29.2	M515	29.0	28.8	--
Voltage - Aft Battery 1	M14	29.1	M541	29.1	--	28.9
Voltage - Aft Battery 2	M15	60.0	M540	59.8	60.6	--
Voltage - Fwd Battery 1	M16	29.9	M543	29.9	--	28.9
Voltage - Fwd Battery 2	M18	28.6	M542	28.9	--	28.8
Current - Fwd Battery 1	M19	10.0	M536	11.0	--	10.5
Current - Fwd Battery 2	M20	4.8	M537	4.7	--	5.0
Current - Aft Battery 1	M21	12	M534	13.0	--	12
Current - Aft Battery 2	M22	24.0	M535	24.0	23.0	23.0
Speed - LOX Pump	T1	8,774	T502	8,824	--	8,813
Speed - LH2 Pump	T2	27,536	T503	27,496	--	27,446

*Compared at T_0 +218 sec

TABLE 11-5
HARDWIRE DATA ACQUISITION SYSTEM

MEASUREMENT TYPE	RECORDED	FAILED	PARTIALLY SUCCESSFUL	SUCCESSFUL (%)
Pressure	77	0	0	100
Temperature	41	0	0	100
Flow	2	0	0	100
Position	10	0	0	100
Voltage/Current	27	0	1	100
Events/Switches	125	0	0	100
Speed	2	0	0	100
Level	1	0	0	100
Vibration	4	1	0	75
Miscellaneous	4	0	0	100
TOTALS	286	1	1	99.65

TABLE 11-6
HARDWIRE MEASUREMENT DISCREPANCIES

MEASUREMENT NO.	PARAMETER	REMARKS
E555	Vibration-Oxidizer Turbopump-Radial	Measurement failed to produce valid data during the acceptance firing because of noise spikes throughout the test. The cause of the failure is unknown.
M723	Reference Voltage-GSE, 5 vdc	The measurement dropped out three times during the LOX loading. It was normal the remainder of the test. The discrepancy was found to be a bad submultiplexer relay in the Beckman 210 Digital Data System.

12. ELECTRICAL POWER AND CONTROL SYSTEMS

12.1 Electrical Control System

All control system events that function as a direct result of a switch selector command performed satisfactorily as shown in the sequence of events (section 5). The system performance of non-programmed events is presented in the following paragraphs.

12.1.1 J-2 Engine Control System

All event measurements verify that the engine control system had responded properly to the engine start and cutoff commands.

The engine cutoff signal was non-programmed. This cutoff was initiated by the propellant utilization (PU) processor which indicated that a 1 percent LOX level had been attained.

12.1.2 Range Safety System

During the engine burn phase, the range safety system was employed for verification of performance integrity. Evaluation of the measurements in table 12-1 and figure 12-1 verified that the range safety system performed satisfactorily.

12.1.3 Control Pressure Switches

A review of the event and pressure measurements listed in table 12-2 verified that each control item functioned properly. The actuation and deactuation pressures for pre- and post-acceptance firing are presented in table 3-3.

12.1.4 Vent Valves

The LOX and LH2 vent valves were commanded open and close by GSE, bypassing the switch selector. The vent valves responded to these commands although the LOX vent valve close indication chattered 13 times beginning approximately 5.224 sec before engine start and the LH2 directional vent valve ground position indication chattered 126 times over a period of 1.422 sec during the boil-off period. The measurements used in this evaluation are listed in table 12-3.

12.1.5 Chilldown Shutoff Valves

A review of the measurements listed in table 12-4 indicated that the LOX valve closed command was never received and no talkback after the valve was commanded open. The close command was not received because of a digital events recorder (DER) problem as verified by the tests results tape. The open talkback was not received because of a microswitch failure on the valve. The commands were issued and received by the valve as designed.

12.1.6 Fill and Drain Valves (LH2 and LOX)

Prior to simulated liftoff the fill and drain valves were commanded closed through the umbilical. These valves remained closed throughout the acceptance firing. After firing, the fill and drain valves were opened to drain the remaining propellants. The data review of the measurements listed in table 12-6 verified that the valves performed satisfactorily.

12.1.7 Depletion Sensors

The evaluation of the measurements listed in table 12-7 and figure 12-2 showed that LH2 sensor No. 1 cycled abnormally from wet to dry after submergence. All other depletion sensors (LH2 and LOX) performed as expected.

12.2 APS Electrical Control System

The APS simulator No. 188B was activated for verification of the APS No. 1 and No. 2 engines control functions.

Exhibits of the engine feed valves verify that the electrical control system performed within prescribed limitations.

The monitored results are shown in the following table:

Measurement No.	Function	Specified Minimum Value	Actual Value
K132	APS Engine 1-1/1-3 Feed Valves Open	3.2 vdc	4.05 vdc
K133	APS Engine 1-2 Feed Valves Open	3.2 vdc	4.1 vdc
K134	APS Engine 2-1/2-3 Feed Valves Open	3.2 vdc	3.95 vdc
K135	APS Engine 2-2 Feed Valves Open	3.2 vdc	4.05 vdc

The specified minimum value of 3.2 vdc indicates that all of the feed valves were operating.

12.3 Electrical Power Systems

The electrical power system performed satisfactorily throughout the acceptance firing. The voltage, current and simulator temperature profiles are shown in figures 12-3 through 12-5.

12.3.1 Static Inverter - Converter

The static inverter - converter operated within its required limits during the firing. Its actual values are shown in the following table:

Characteristics	Maximum	Minimum	Acceptable Limits
Voltage (vrms)	114.5	114.2	115.0 ± 3.45
Voltage (vdc)	5.07	5.06	5.0 ± 0.5
Voltage (vdc)	21.92	21.4	21.0 $^{+1.5}_{-1.0}$
Frequency (Hz)	400.7	400.6	400.0 ± 6.0

12.3.2 5-Volt Excitation Modules

The performance of the forward No. 1 and No. 2, and aft 5-volt excitation modules was satisfactory during the acceptance firing. The actual values are shown in the following table:

Characteristics	Maximum	Minimum	Acceptable Limits
Aft Voltage (vdc)	5.02	5.01	5.0 ±0.05
Forward 1 Voltage (vdc)	4.99	4.98	5.0 ±0.05
Forward 2 Voltage (vdc)	4.98	4.97	5.0 ±0.05

12.3.3 Chilldown Inverters

The chilldown inverters performed satisfactorily during the acceptance firing. During the operation of the chilldown inverters, some data exhibited approximately 2 percent noise; since this occurred prior to engine start, it did not degrade any of the engine performance data.

TABLE 12-1
RANGE SAFETY SYSTEM MEASUREMENTS

MEASUREMENT NO.	TITLE
K98	Event - R/S No. 1 Arm, Cutoff, Destruct Indication
K99	Event - R/S No. 2 Arm, Cutoff, Destruct Indication
K141	Event - EBW No. 1 Pulse Sensor Indication
K142	Event - EBW No. 2 Pulse Sensor Indication
K659	Event - R/S No. 1 Arm and Engine Cutoff Indication, instrumentation unit (IU)
K660	Event - R/S No. 2 Arm and Engine Cutoff Indication, IU
M30	Volt - F/U 1 EBW Range Safety
M31	Volt - F/U 2 EBW Range Safety
N57	Misc - R/S No. 1 Low Level Signal Strength
N62	Misc - R/S No. 2 Low Level Signal Strength

TABLE 12-2
CONTROL PRESSURE SWITCH EVENTS AND PRESSURE MEASUREMENTS

MEASUREMENT NO.	TITLE	SWITCHING LIMITS
K102	Event - LOX Prepress Flight Switch - Energized	36.5-41.0 psia
D179 D180	Press - Oxid Tank Ullage EDS 1 and 2 Pressure	-
K611	Event - Fuel Tank Flight Control Switch - Energized	26.5-30.0 psia
K524	Event - Fuel Tank Control Valve Solenoid - Energized	26.5-30.0 psia
D177 D178	Press - Fuel Tank Ullage EDS 1 and 2 Pressure	-
K105	Event - Engine Pump Purge Control Regulated Back-up Switch De-energized	105-130 psia
K566	Event - Engine Pump Purge Control Module Valve Energized	105-130 psia
D50	Press - Engine Pump Purge Regulator Pressure	
K131	Event - LOX Chilldown Pump Switch De-energized	49-54 psia
K565	Event - LOX Pump Purge Control Motor Valve - Energized	49-54 psia
D103	Press - He to LOX Motor Control Pressure	
K156	Event - LOX Tank Regulator Back-up Pressure Switch - Energized	465 psia actuation
D225	Press - Cold Helium Control Valve Inlet	

TABLE 12-3
VENT VALVE MEASUREMENTS

MEASUREMENT NO.	TITLE	VALVE
K1 K532	Event - Fuel Tank Vent Valve Closed	LH2 Vent
K17 K542	Event - Fuel Tank Vent Valve Open	LH2 Vent
K516	Event - Fuel Tank Vent Valve Open - Energized	LH2 Vent
K2 K533	Event - LOX Tank Vent Valve Closed	LOX Vent
K16 K543	Event - LOX Tank Vent Valve Open	LOX Vent
K575	Event - LOX Tank Vent Valve Open - Energized	LOX Vent
K113	Event - LH2 Tank Directional Vent Valve C - Closed	LH2 Directional Vent
K114	Event - LH2 Tank Directional Vent Valve D - Closed	LH2 Directional Vent
K561	Event - LH2 Tank Directional Vent Valve - Ground Position	LH2 Directional Vent
K562	Event - LH2 Tank Directional Vent Valve - In-Flight Position	LH2 Directional Vent

TABLE 12-4
CHILLDOWN SHUTOFF VALVES MEASUREMENTS

MEASUREMENT NO.	TITLE
K136 K551	Event - LH2 Chilldown Shutoff Valve Closed
K139 K552	Event - LOX Chilldown Shutoff Valve Closed
K137 K544	Event - LH2 Chilldown Shutoff Valve Open
K138 K545	Event - LOX Chilldown SHutoff Valve Open
K544	Event - LH2 and LOX Chilldown Shutoff Valve Closed - Energized

TABLE 12-5
FILL AND DRAIN VALVES MEASUREMENTS

MEASUREMENT No.	TITLE
K3 K554	Event - Fuel Fill and Drain Valve Closed
K19 K546	Event - Fuel Fill and Drain Valve Open
K4 K553	Event - LOX Fill and Drain Valve Closed
K18 K547	Event - LOX Fill and Drain Valve Open

TABLE 12-6
DEPLETION SENSOR MEASUREMENTS

MEASUREMENT NO.	TITLE
K597	Event - LH2 Depletion Sensor No. 1 Wet
K598	Event - LH2 Depletion Sensor No. 2 Wet
K599	Event - LH2 Depletion Sensor No. 3 Wet
K676	Event - LH2 Depletion Sensor No. 4 Wet
K601	Event - LOX Depletion Sensor No. 1 Wet
K602	Event - LOX Depletion Sensor No. 2 Wet
K603	Event - LOX Depletion Sensor No. 3 Wet
K675	Event - LOX Depletion Sensor No. 4 Wet

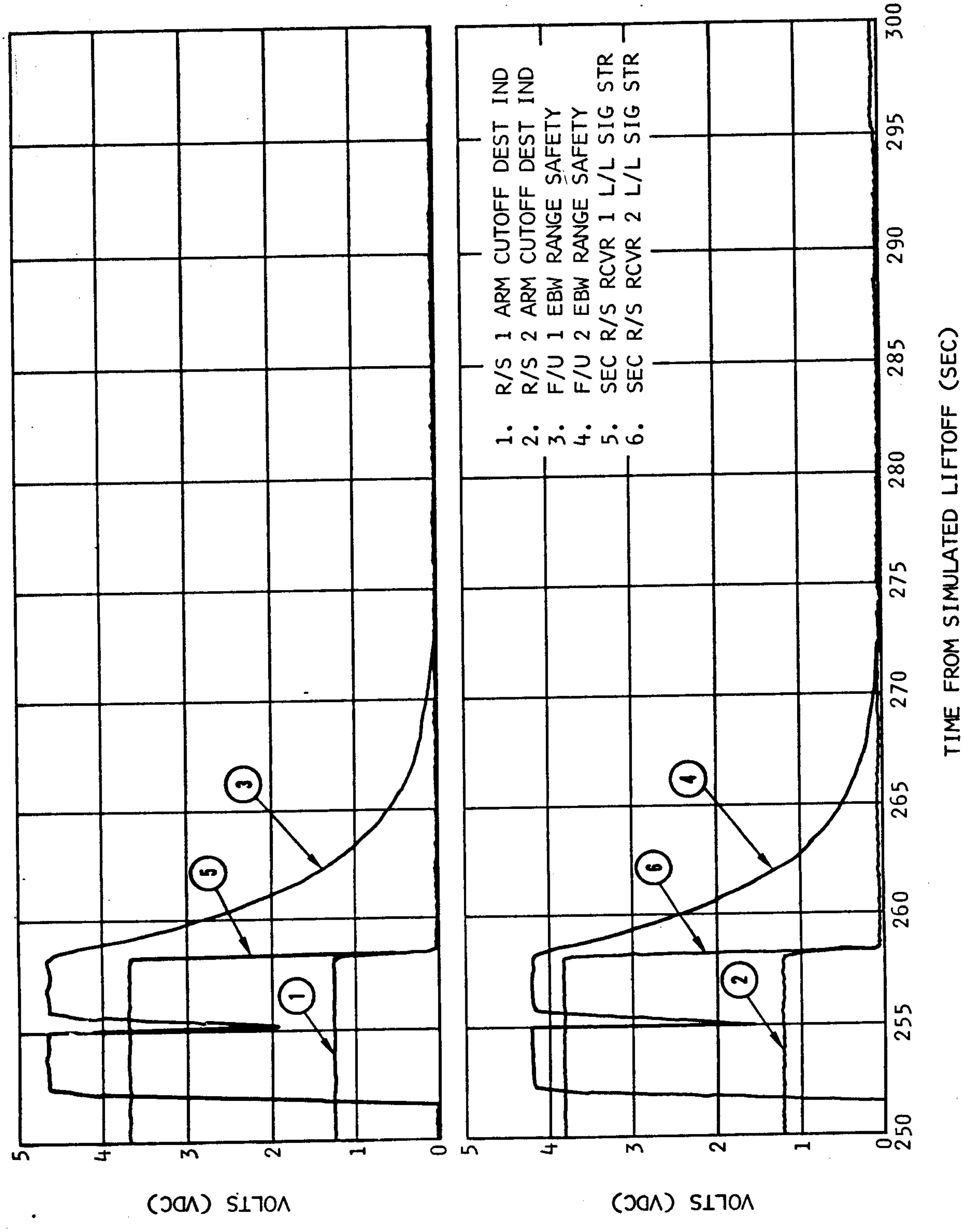


Figure 12-1. Range Safety Data

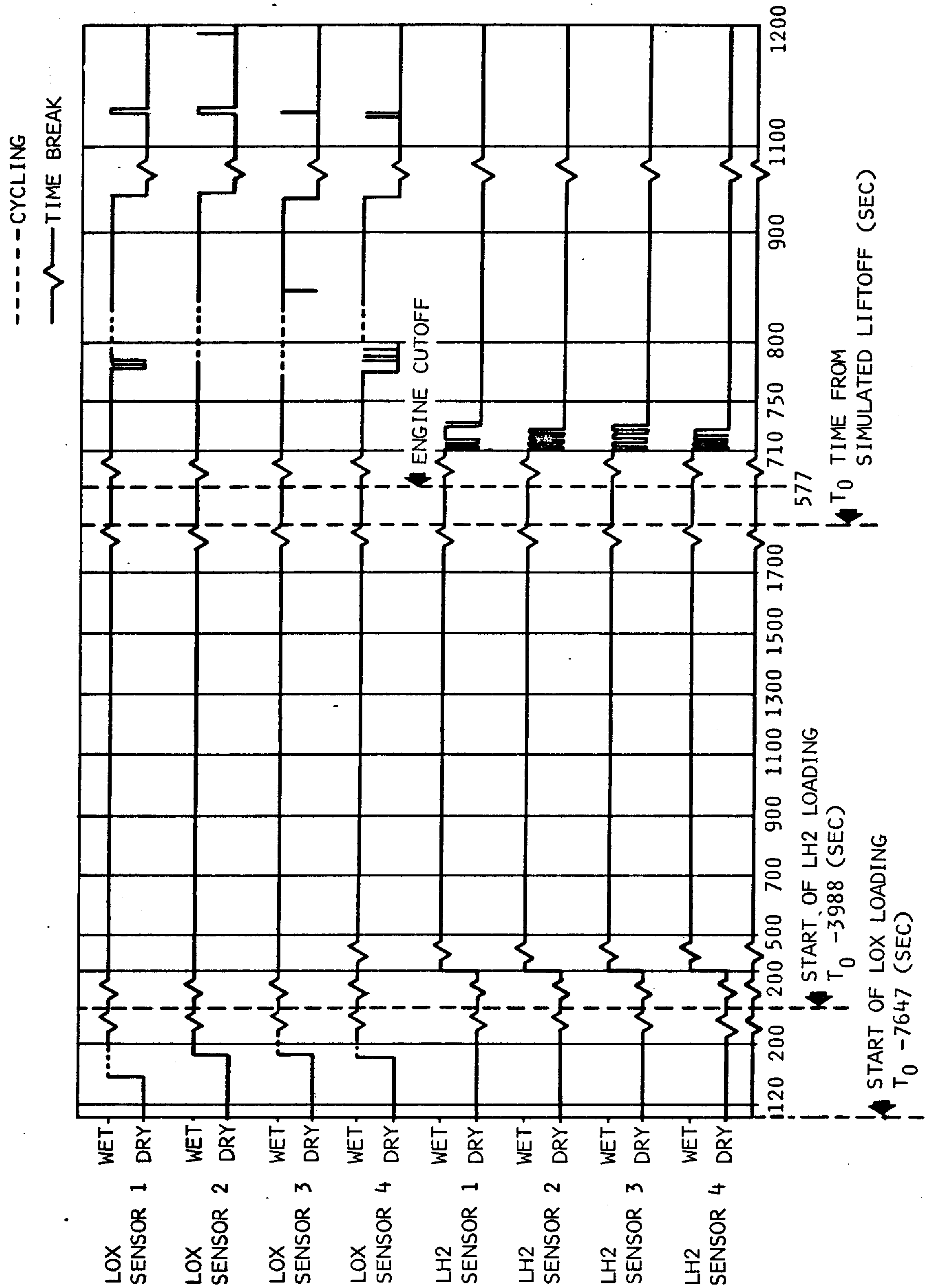


Figure 12-2. Depletion Sensor Data

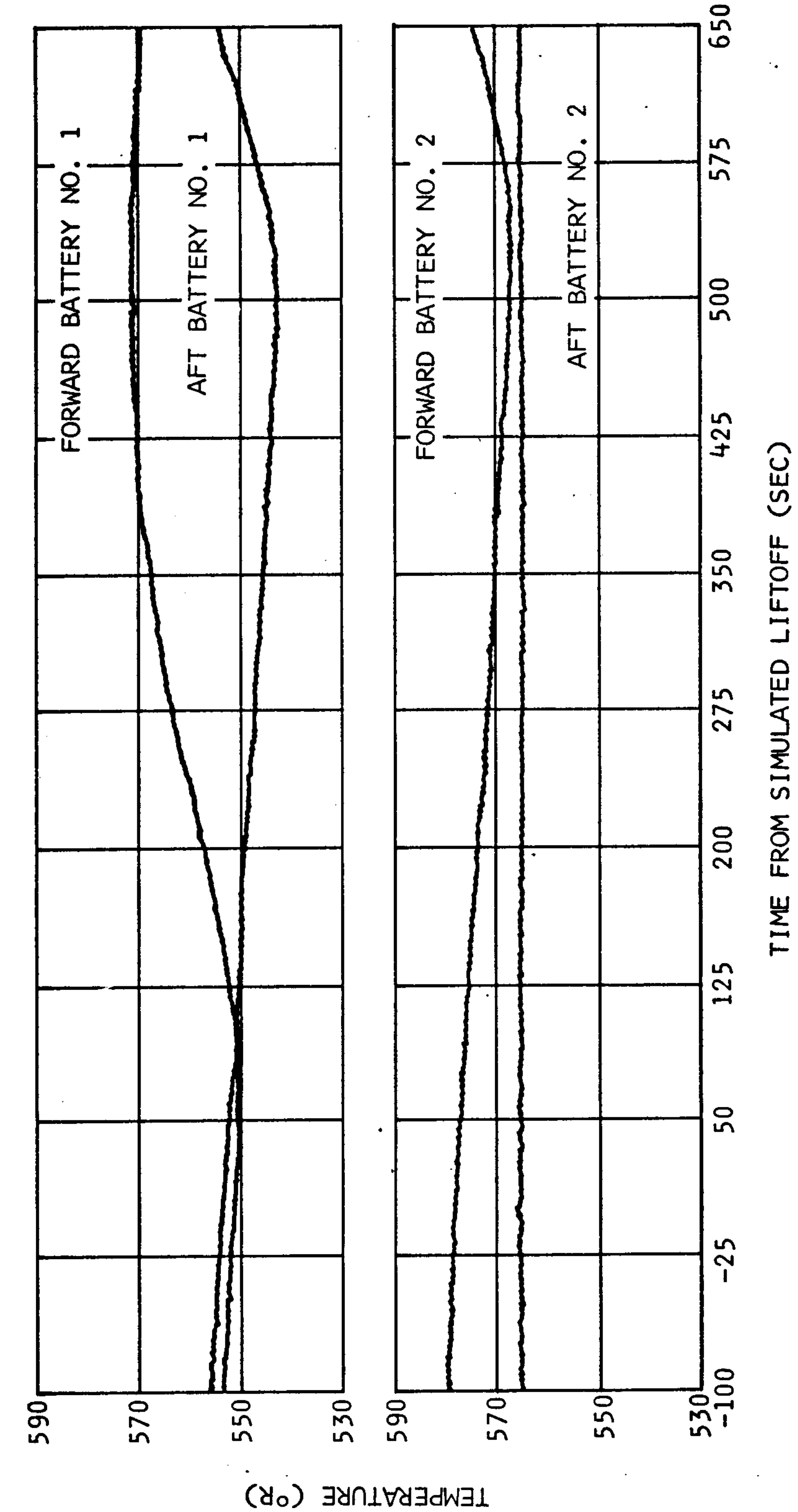
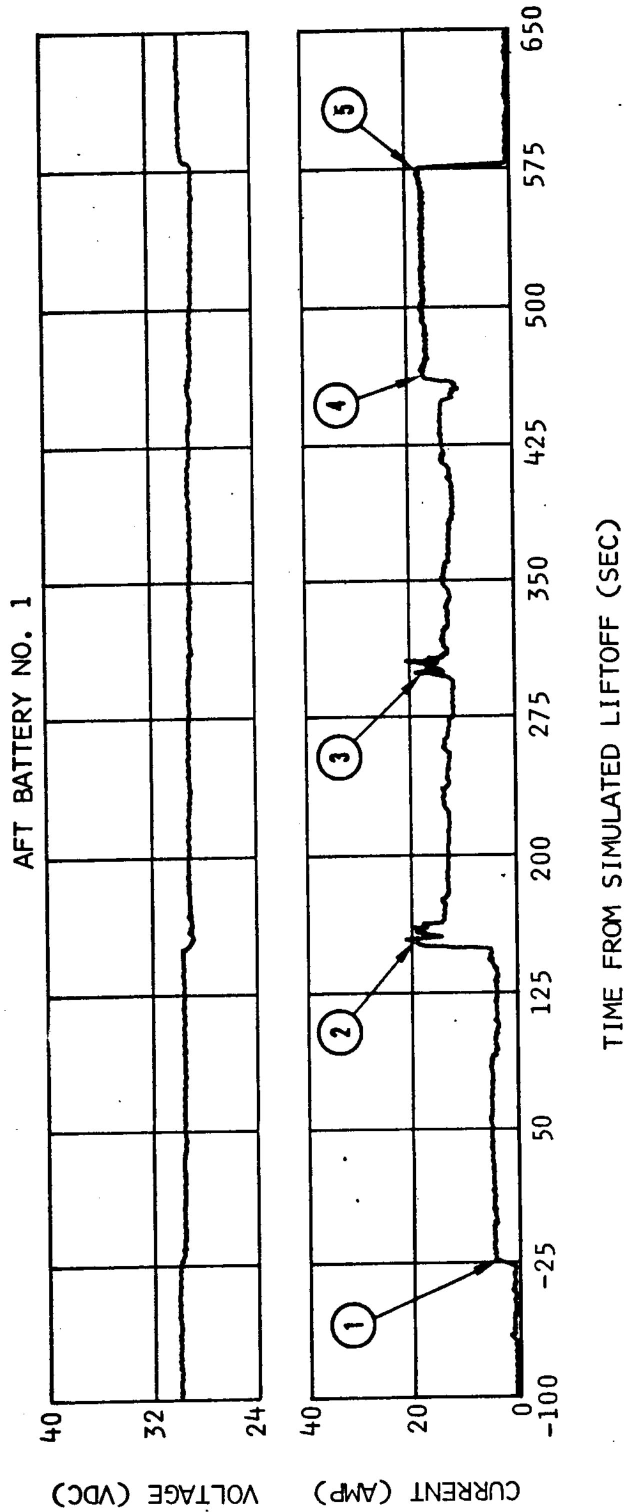
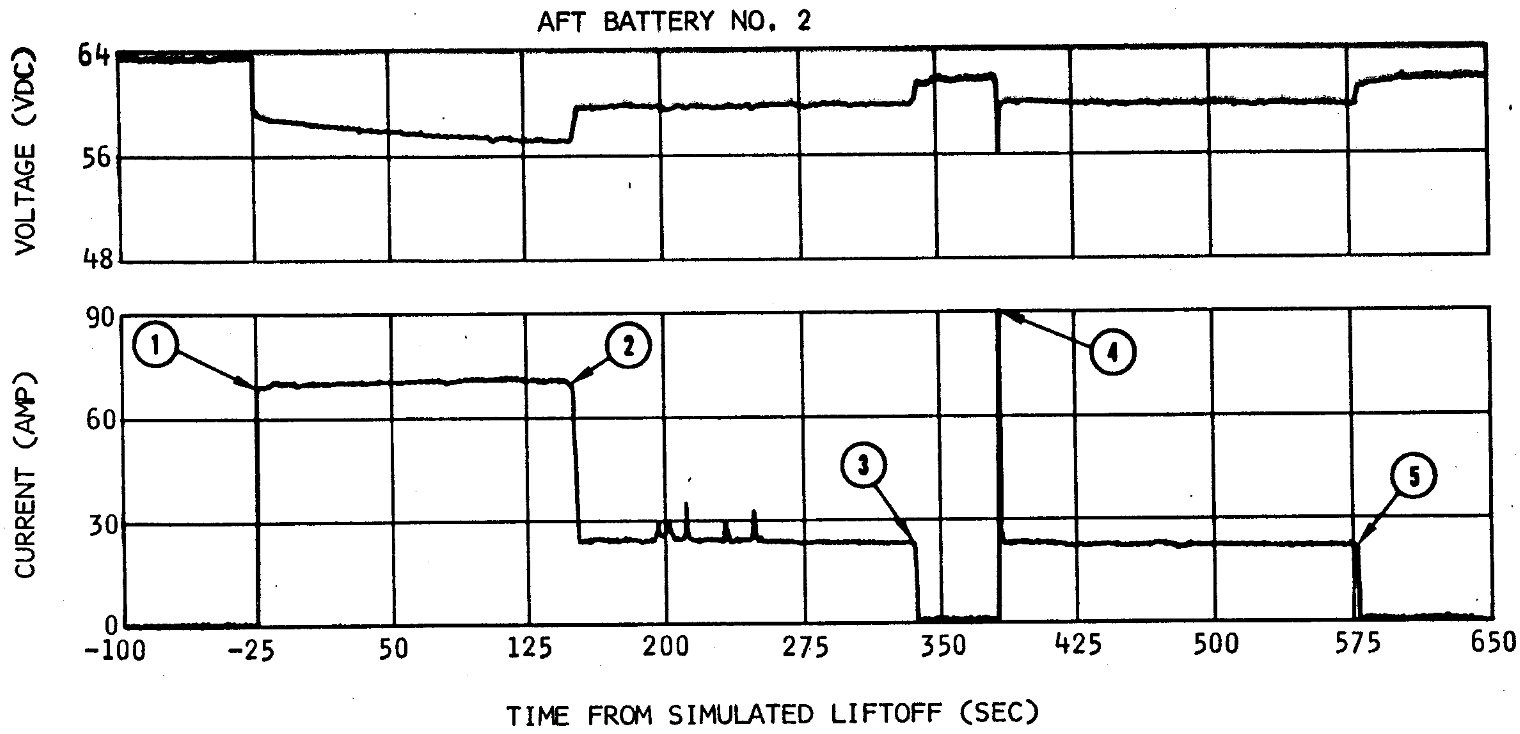


Figure 12-3. Battery Temperature Data



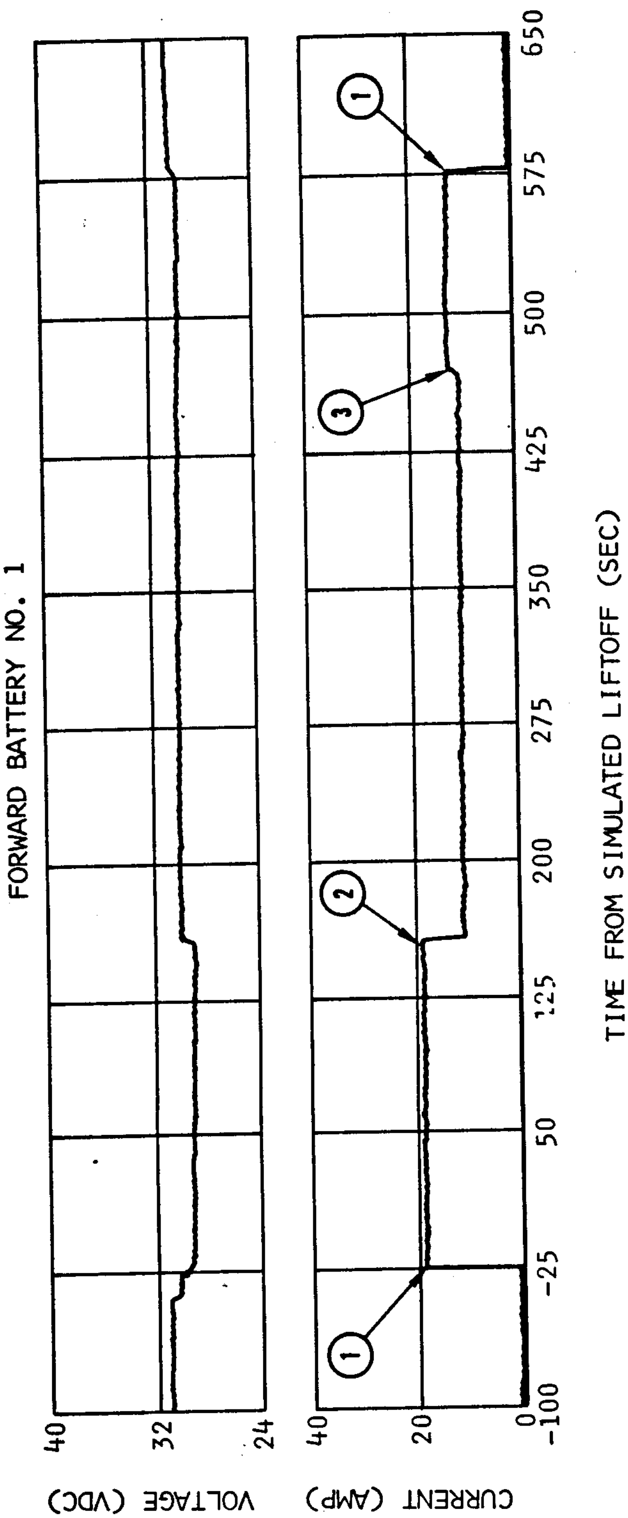
1. INTERNAL POWER
2. ENGINE START
3. BATTERY NO. 1 HEATER ON
4. BATTERY NO. 2 HEATER ON
5. ENGINE CUTOFF

Figure 12-4. Aft Battery Voltage & Current Profiles (Sheet 1 of 2)



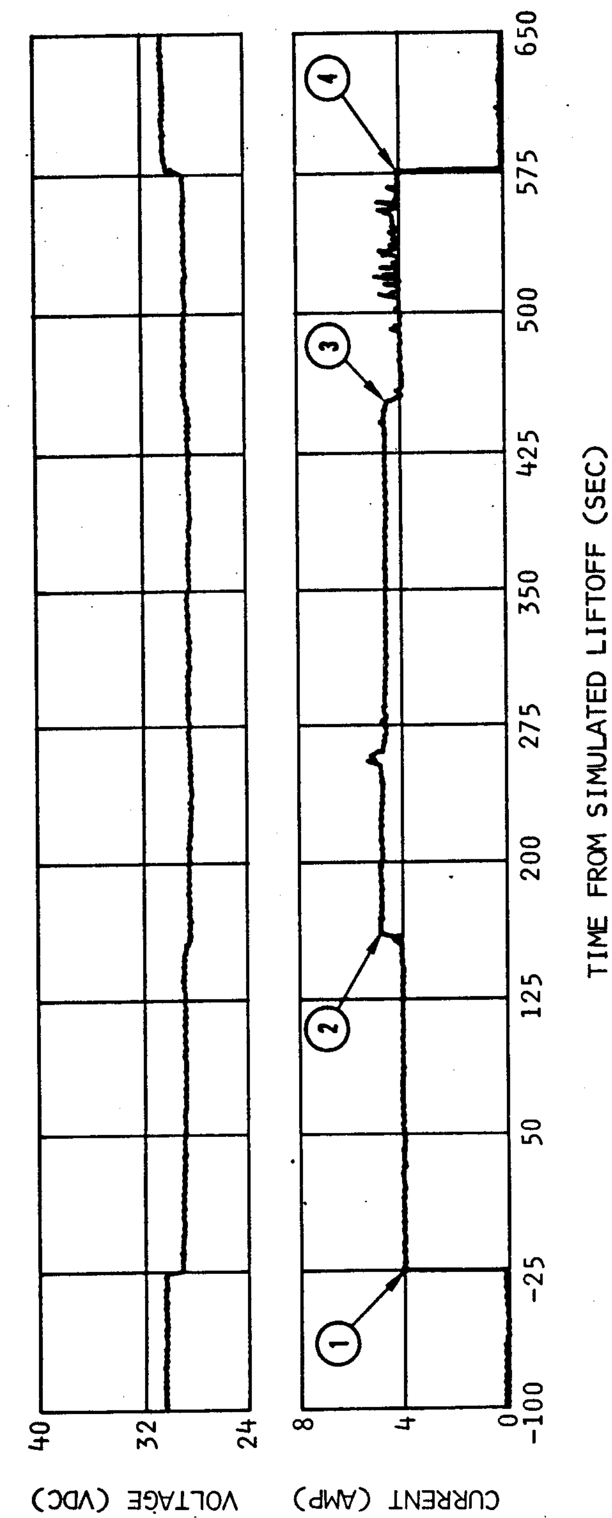
1. INTERNAL POWER
2. LOX AND LH2 CHILLDOWN INVERTERS OFF
3. AUXILIARY HYDRAULIC PUMP FLIGHT MODE OFF
4. AUXILIARY HYDRAULIC PUMP FLIGHT MODE ON
5. AUXILIARY HYDRAULIC PUMP OFF

Figure 12-4. Aft Battery Voltage & Current Profiles (Sheet 2 of 2)



1. POWER TRANSFER
2. FORWARD BATTERY NO. 1 HEATERS OFF
3. FORWARD BATTERY NO. 2 HEATER ON

Figure 12-5. Forward Battery Voltage & Current Profiles (Sheet 1 of 2)



1. POWER INTERNAL
2. PU ACTIVATE ON
3. PU RATIO VALVE MOVEMENT
4. PU ELECTRONIC POWER OFF

Figure 12-5. Forward Battery Voltage & Current Profiles (Sheet 2 of 2)

13. HYDRAULIC SYSTEM

The engine was successfully positioned and gimbaled during the hydraulic system test program. Two portions of objective No. 9 of Douglas Report No. SM-47458A, *Saturn S-IVB-208 Stage Acceptance Firing Test Plan,* dated November 1966 were partially missed; namely, a leaking accumulator permitted GN2 loss prior to the firing in excess of the allowable limits defined in item a.1., and the engine-driven hydraulic pump overshoot pressure fluctuations were in excess of the allowable limits defined in item b.1.; this was attributed to the accumulator piston being bottomed due to the GN2 leakage. The system function, to position the engine in response to guidance commands, was not adversely affected. Significant event times are presented in the following table:

Event	Time from Simulated Liftoff (sec)
Aux Pump ON	-674
Simulated liftoff	0
Engine-driven Pump START	151
Support Links DROPPED	185 (yaw) 186 (pitch)
Gimbal Program START	195
Gimbal Program STOP	252
Auxiliary Pump OFF	336
Auxiliary Pump ON	383
Engine Cutoff/Engine-driven Pump STOP	578
Auxiliary Pump OFF	588

13.1 System Pressure at Salient Times

The GN2 precharge, normally 2,350 ±50 psia at 70 deg F was 2,015 psia at 54 deg F prior to T_0 -674 despite deliberate "overcharging" before the firing. GN2 leakage through the bootstrap piston vent valve path was observed at a rate of 5 to 50 psia/hr, or up to 2,650 times the allowable maximum of 6 scc/hr. This leakage requires replacing the P/N 1B29319-519 (S/N 23) accumulator-reservoir.

Auxiliary pump pressure was 3,590 psia at system leakage flow, the engine-driven pump steady-state output was 3,665 psia (digital data). Overshoot at start was 4,130 psia, and 3,225 to 4,180 psia during the gimbal program. The objective limit of 3,400 to 3,900 psia was exceeded as a direct result of the accumulator piston being bottomed due to the low precharge. This engine-driven pump had already been scheduled for replacement with the improved compensator attachment model; therefore, performance evaluation of this particular unit is of minimal importance. The engine-driven pump did assume the system leakage flow requirement during steady-state operation. The power requirement was 0.93 hp.

Return pressure accurately reflected system pressure. Prior to auxiliary pump ON at T -674, it was 67 psia. Prior to ignition, 177 psia was the value, increasing to 181 psia following start transients and the gimbal program. Some "peaking," which tracks the system pressure, was seen during the start transients (200 psia) and gimbal program (200 psia).

13.2 Reservoir Level at Salient Times

Reservoir level prior to T_0 -674 was 89 percent (equivalent to 92.5 percent at 70 deg F), increasing to 96 percent following auxiliary pump OFF after cutoff. Minimum was 27 percent shortly after auxiliary pump start when the accumulator piston bottomed.

13.3 Hydraulic Fluid Temperature History

Time from Simulated Liftoff (sec)	Engine-Driven Pump Inlet (°F)	Reservoir (°F)	Accumulator GN2 (°F)
-674 (auxiliary ON)	45	47	54
150 (ignition)	71	85	62
195	73 to 83	67	62
252		67	62
577 (cutoff)	116	76	62
588 (auxiliary OFF)	118	76	62

13.4 Engine Side Loads

Peak loads in the support links during engine start transients are presented in the following table:

Item	Load (lbf)	
Pitch link	+17,000	-14,000
Yaw link	+28,000	-19,500

13.5 Hydraulic Fluid Flowrates

Approximations from reservoir fill and emptying rates are presented in the following table:

Item	Flowrate (gpm)	Allowable Flowrate (gpm)
System internal leakage	0.43	0.4 to 0.8
Auxiliary pump maximum	1.58	1.50 min

13.6 Miscellaneous

Thrust offset approximation from actuator differential pressure immediately prior to and following cutoff, using 164,000 net thrust, was 0.016 in. from the stage longitudinal axis, 26.5 deg from fin plane II toward fin plane III.

14. FLIGHT CONTROL SYSTEM

The dynamic response of the hydraulic-servo thrust vector control system during the acceptance firing of the S-IVB-208 stage was measured while the J-2 engine was gimbaled. The performance of the pitch and yaw hydraulic-servo control systems was found to be acceptable.

14.1 Actuator Dynamics

The frequency response test of the pitch and yaw hydraulic-servo control system for a $\pm 1/2$ deg sinusoidal signal between 0.6 and 9 cps, and for a $\pm 1/4$ deg sinusoidal signal between 0.6 and 2 cps verified the acceptability of the actuator responses. The acceptable limits and the gain and phase plots within these limits are presented in figures 14-1 and 14-2.

14.2 Engine Slew Rates

A nominal 2 deg step command was applied to the pitch and yaw actuators from which the engine slew rates were determined. The minimum acceptable engine slew rate is 8 deg/sec, which corresponds to an actuator piston travel rate of 1.66 in./sec. A nominal slew rate for a 2 deg step without the effects of gimbal friction is 13.6 deg/sec. The measured values were found to be acceptable and are presented in the following table:

Actuator	Condition	Engine Travel (deg)	Engine Slew Rate (deg/sec)
Pitch	Retract	0.0 to +2.0	11.0
	Extend	+2.0 to 0.0	10.9
	Extend	0.0 to -2.0	12.2
	Retract	-2.0 to 0.0	10.7
Yaw	Extend	0.0 to +2.0	12.1
	Retract	+2.0 to 0.0	11.5
	Retract	0.0 to -2.0	12.3
	Extend	-2.0 to 0.0	11.1

The minimum engine slew rate obtained is 10.7 deg/sec which corresponds to an actuator piston travel rate of 2.22 in./sec when using a conversion

conversion of 4.83 deg of engine movement per inch of actuator travel; thus, in all cases, each actuator exceeded the minimum acceptable piston travel rate of 1.66 in./sec.

14.3 Differential Pressure Feedback Network

The differential pressure feedback network in the pitch and yaw hydraulic servo valves was operating properly since adequate system damping was demonstrated by observing the actuator differential pressure measurements during the two deg step response tests. The differential pressures decreased in amplitude as a function of time without sustained oscillations (figure 14-3).

14.4 Cross-Axis Coupling

Cross-axis coupling is obtained from actuator piston differential pressure data. The cross-axis coupling from the yaw to pitch plane did not exceed 8 percent and from the pitch to yaw plane, did not exceed 10 percent.

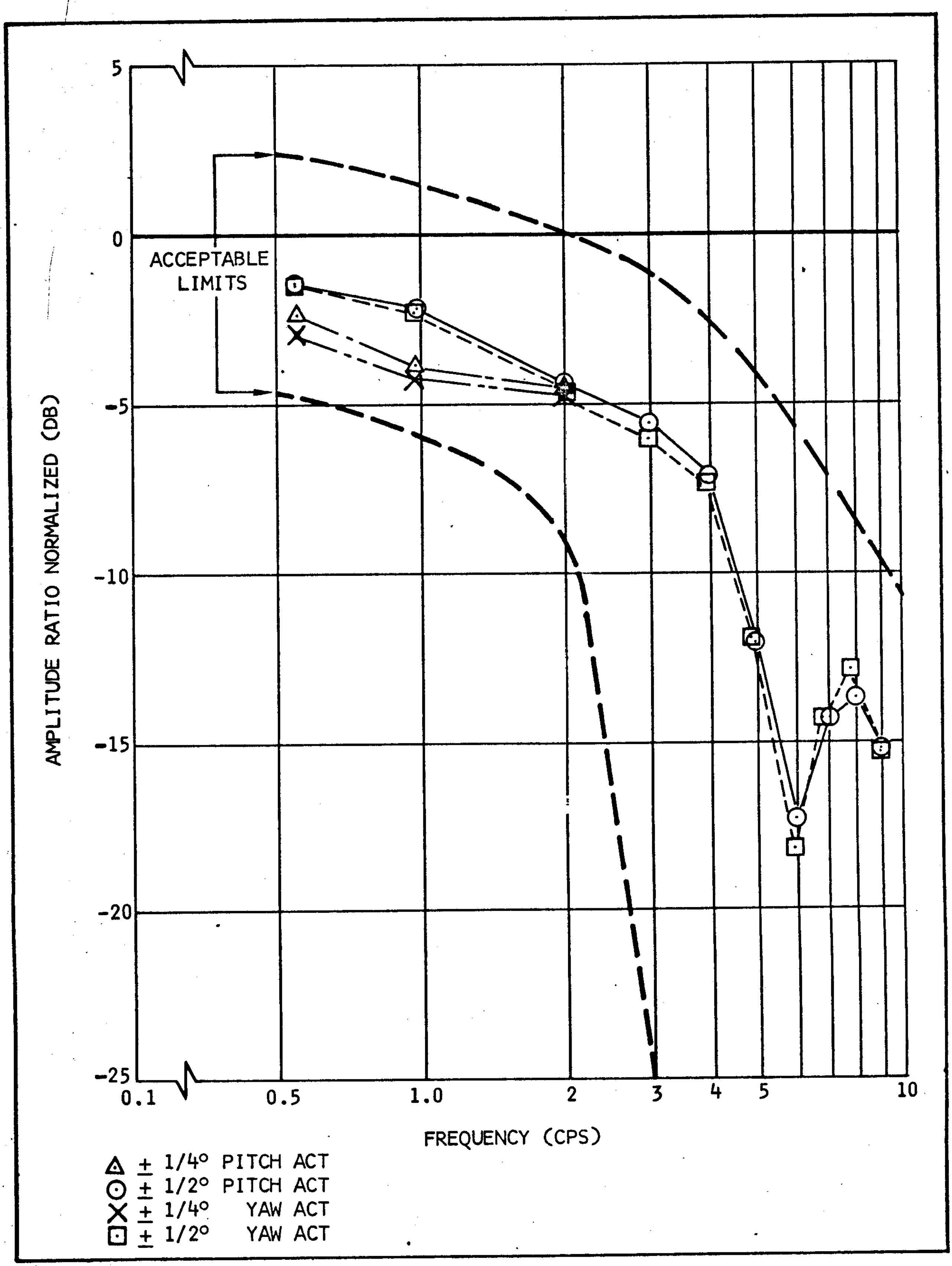


Figure 14-1. Actuator Response (GAIN)

27 March 1967

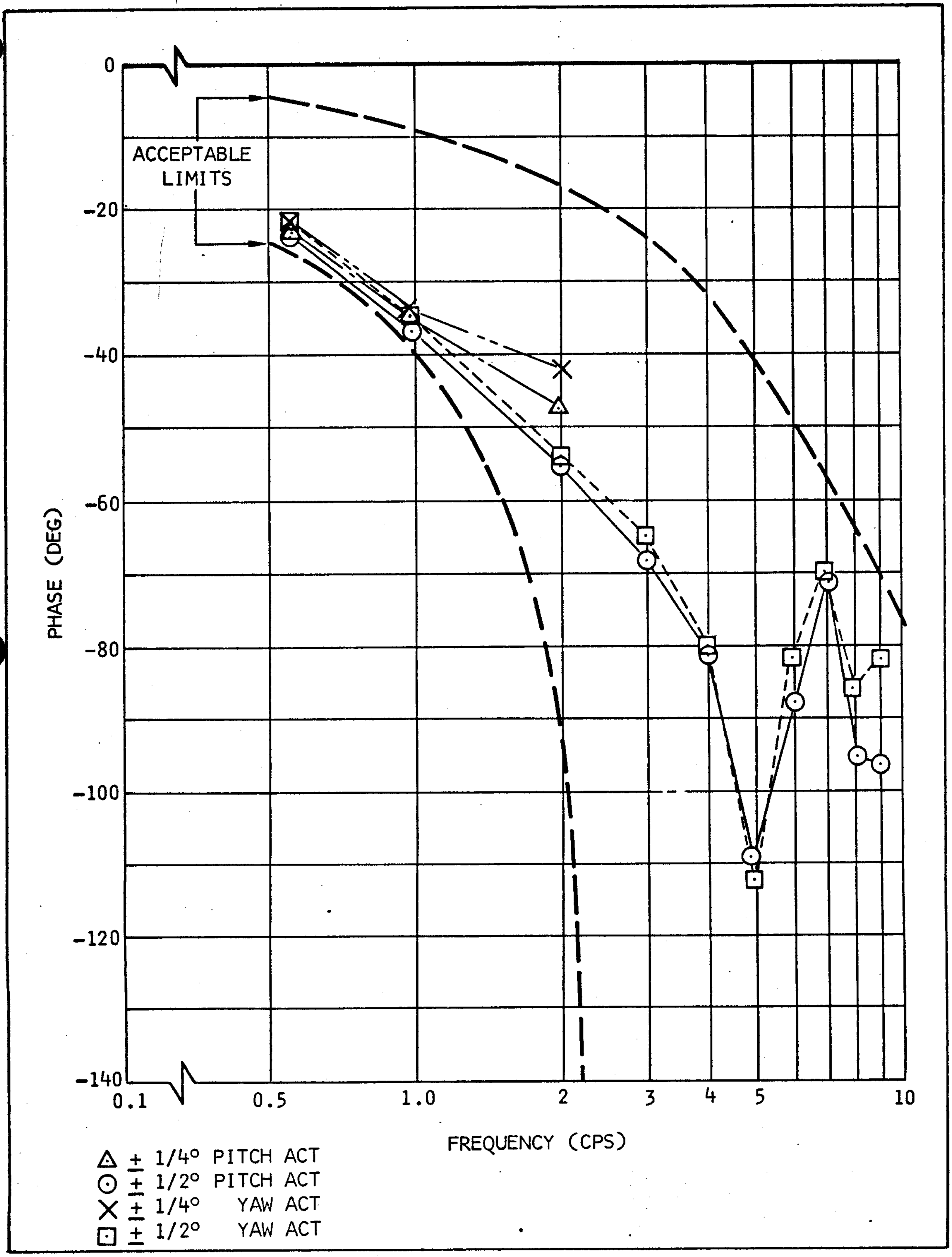


Figure 14-2. Actuator Response (PHASE LAG)

27 March 1967

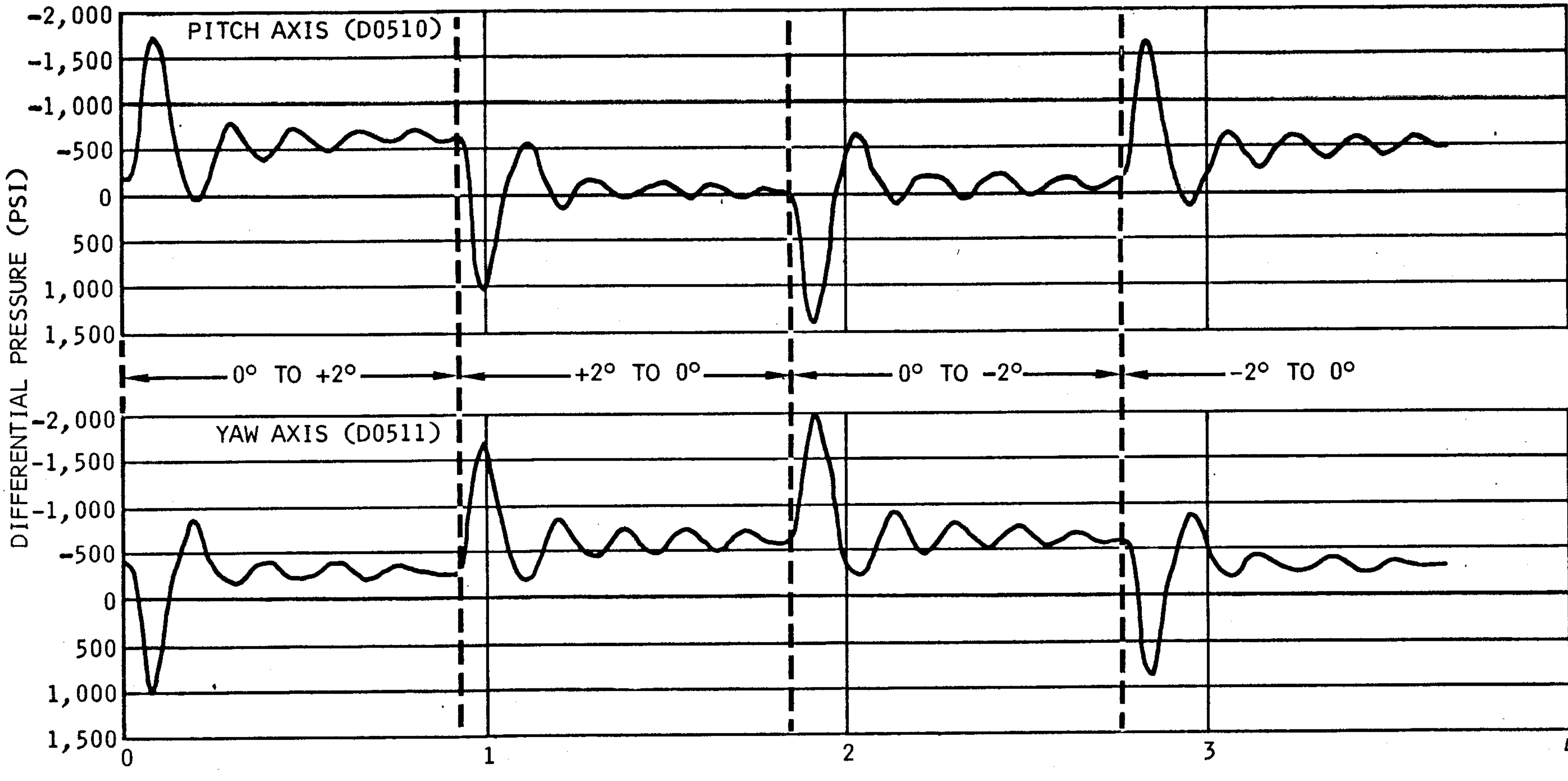


Figure 14-3. Actuator Differential Pressure (±2 deg Transient Response)

15. STRUCTURAL SYSTEMS

Structural integrity of the S-IVB-208 stage was maintained for the vibration, temperature, and thrust load conditions of the acceptance firing. No structural irregularities were detected during the post firing inspection. Following the explosion of the S-IVB-503 stage at adjacent Beta III test stand on 20 January, 1967 the S-IVB-208 stage was again inspected, and no structural damage was detected.

15.1 Common Bulkhead

The results of the gas sample surveys, combined with satisfactory common bulkhead pressure decay checks, indicate the bulkhead is sound and leak tight. The bulkhead internal pressure during the firing was less than 1 psia. The results of the pressure checks and gas sample analyses during prefire pumpdowns, crygoenic loading, static firing, and post-firing verifications, are presented in Douglas Report No. SM-37545, *S-IVB-208 Stage Acceptance Firing (15 Day) Report*, dated February 1967.

15.2 LH2 Tank Interior

A postfire visual inspection of the LH2 tank interior was made from the forward dome access door. The inspection revealed no visual discrepancies.

15.3 Exterior Structure

A visual inspection of the thrust structure, LOX tank aft dome, aft skirt, LH2 tank cylindrical section, LH2 tank forward dome, and forward skirt revealed no structural damage after the full duration firing. The inspection revealed no debonding of standoff supports, tunnel clips, or the aft skirt fabric purge membrane.

15.4 Post S-IVB-503 Stage Explosion Inspections

Following the explosion of the S-IVB-503 flight stage at the adjacent Beta III test stand, the S-IVB-208 stage was again inspected. No structural damage was detected. The S-IVB-208 stage, which was in the Beta I test stand, evidently was not struck by any flying objects since the stage had no dents or major scratches. Two minor scratches were found in the paint on the forward dome near the LH2 repressure connectors, but these scratches were believed not to be associated with the S-IVB-503 stage incident. The scratches were painted over for corrosion protection.

The S-IVB-208 stage was approximately 1,860 ft from the S-IVB-503 stage at the time of the explosion. From external overpressures, the forward dome theoretically is the most critical structure of the stage. By analytical methods, it has been computed that an overpressure of 0.45 psid is required to buckle the dome. Actual pressure data from the S-IVB-503 stage explosion was used for computing the corresponding overpressure at the S-IVB-208 stage location. From the measured peak blast pressure of 2.5 psig at a radial distance of 240 ft from Beta III test stand (sensor 6B), the overpressure at the forward dome of the S-IVB-208 stage was calculated to be 0.16 psid. Thus, it appears that the blast pressure on the S-IVB-208 stage was substantially below the critical buckling pressure of 0.45.

As a precautionary measure in view of the overpressure applied externally to the S-IVB-208 stage, a leak check was applied to the faying surface cavity between the "Y" extrusion closing rings of the common bulkhead and the LOX tank wall. This narrow cavity or spacing circumvents the periphery of the common bulkhead and extends fore and aft over 7-1/2 in. length between the fillet welds. The two extrusion rings are seam welded together centrally to seal the faying surface cavity from the common bulkhead honeycomb core. A gas pressure change in the faying surface cavity (when the tanks are pressurized) would reveal any significant gas leakage through fillet welds or huckbolts attaching the extrusion assembly to the LOX tank wall. This leak check was conducted with nitrogen at 15 psig in the LOX tank and 10 psig in the LH2 tank. There was no change of pressure in the faying surface cavity which verified structural integrity.

The structure of the dummy aft interstage was also investigated for structural integrity after the explosion. No visual damage was evident. Stress analysis of the interstage assembly using conservative explosion pressure assumptions and an ultimate factor of safety of

1.5 gave a minimum margin of safety of 0.12 for the critical ring segment-to-segment joint of the upper frame (Douglas Drawing No. 1A66366, change W). Thus, it is concluded that the dummy aft interstage did not yield under the pressure loads from the S-IVB-503 stage explosion.

16. THERMOCONDITIONING AND PURGE SYSTEMS

16.1 Aft Skirt Thermoconditioning and Purge System

The aft skirt air purge was initiated prior to LOX loading, switched to GN2 just prior to LH2 loading, and maintained throughout the acceptance firing until completion of the final tank purges. The system performed satisfactorily throughout the firing.

16.1.1 Aft Skirt Purge Flowrate

The flowrate for both air and GN2 was maintained between 3,300 and 3,600 scfm throughout the acceptance firing.

16.1.2 Aft Skirt Purge Temperature

The aft skirt umbilical inlet temperature (C0715) vaired between 572 and 576 deg R (112 and 116 deg F) from T_0 -1,500 sec to T_0 +1,000 sec. The aft skirt temperature (for air or GN2) at the APS module thermoconditioning system outlet sensors (C0663) remained between 549 and 551 deg R (89 and 91 deg F) throughout the acceptance firing.

16.1.3 Aft Skirt Umbilical Inlet Pressure

The umbilical inlet pressure (D0767) was constant at approximately 16.0 in. H_2O from T_0 -1,500 to T_0 +1,000 sec.

16.1.4 Non-Flight Hardware

a. APS Modules:

The flight modules were replaced with two Model DSV-4B-188B APS simulators at APS positions 1 and 2. These replacements functionally represent the flight module thermoconditioning system.

b. Aft Interstage:

The Model DSV-4B-540 Dummy Interstage was used to support the stage on the test stand. Use of the dummy interstage lowers the aft skirt purge system internal pressures very slightly, but does not materially affect the overall system purge capabilities.

16.2 Forward Skirt Environmental Control and Thermoconditioning Systems

The forward skirt GN2 purge was initiated prior to LOX loading and maintained throughout the acceptance firing until completion of the final tank purges. The Model DSV-4B-359 thermoconditioning system servicer supplied methanol/water coolant fluid to the thermoconditioning system throughout the firing.

16.2.1 Forward Skirt GN2 Flowrate

The GN2 flowrate was maintained at the design conditions of 500-600 scfm throughout the firing.

16.2.2 Forward Skirt GN2 Temperature

The forward skirt GN2 internal temperature (C0768) remained between 490 and 522 deg R (30 and 62 deg F) for the entire acceptance firing.

16.2.3 Forward Skirt Internal Pressure

The forward skirt internal pressure remained well below the relief valve setting of 2.0 in. H_2O from T_0 -1,500 sec to T_0 +1,000 sec.

16.2.4 Forward Skirt Thermoconditioning System

The thermoconditioning system fluid inlet temperature (C0753) remained between 512 and 522 deg R (52 and 62 deg F) for the entire acceptance firing.

16.2.5 Non-Flight Hardware

Model DSV-4B-359 Thermoconditioning System Servicer: The servicer supplies thermally conditioned fluid to the forward skirt cold plates during all field station operations requiring power to the forward skirt electronic equipment. When the S-IVB is staged, the cold plates will receive fluid from the NASA instrument unit thermoconditioning system.

17. RELIABILITY AND HUMAN ENGINEERING

17.1 Reliability Engineering

All functional failures of Flight Critical Items (FCI) and Ground Support Equipment/Special Attention Items (GSE/SAI) were investigated by Reliability Engineering. Significant malfunctions of Flight Critical Items documented are noted in table 17-1.

17.2 Human Engineering

A Human Engineering evaluation was made in support of the Acceptance Firing Program of S-IVB-208 stage. No significant man-machine problems were identified.

TABLE 17-1 (Sheet 1 of 2)
FLIGHT CRITICAL COMPONENTS MALFUNCTIONS

P/N AND S/N	PART NAME	TROUBLE DESCRIPTION	CAUSE	ACTION TAKEN
1A49421-501 S/N 143	Pump, LH2 Aux. Motor Driven, Childown	During the test per procedure 1B70919 Revision 8, the pump was inadvertently turned on and ran for approx 3 minutes in a "dry" condition.	Various cables misconnected. A combination of human errors.	The pump was removed and shipped to A-MRCC for return to the vendor for rework or replacement. The discrepant pump was replaced with a -503 configuration pump, S/N 145.
1A49965-521 S/N 0302	Valve, Shut-off, Chill System	No open talkback indication noted throughout the acceptance firing, beginning with cycling the valve open at 70% LH2 level. The valve operation was verified by a special chill-down flowrate check. The talkback discrepancies were verified by mainstage panel and response signal conditioner.	To be determined.	The valve was removed and sent to A-MRCC for further evaluation and SFA recommendation. The discrepant valve was replaced with a like configuration valve, S/N 0301.
1A49965-519 S/N 0104	Valve, Shut-off, Chill System	No open talkback was noted after tank pressurization to approx 25 psia with the LH2 tank filled to the 100% level. The valve operation was verified by a special chilldown flowrate check. Satisfactory talkback was received during critical	To be determined	The valve was removed and sent to A-MRCC for further evaluation. The discrepant valve was replaced with a like configuration valve, S/N 0509.

TABLE 17-1 (Sheet 2 of 2)
FLIGHT CRITICAL COMPONENTS MALFUNCTIONS

P/N AND S/N	PART NAME	TROUBLE DESCRIPTION	CAUSE	ACTION TAKEN
1A49965-519 S/N 0104 (Continued)		components cycling as verified by mainstage panel and the response signal conditioner.		
1B29319-519 S/N 00023	Accumulator Reservoir Assy	During post-test hydraulic system checkout, the pressure on the GN2 side of the accumulator was decaying at the rate of 50 psia/hr. Investigation showed leakage was apparently past the seals into hydraulic side of accumulator and out through the pressure relief valve.	Believed to be bad or damaged seals.	The accumulator will be returned to A-MRCC for further evaluation as soon as a replacement becomes available at A45.
1B57781-501 S/N 0019	Module, Cold Helium Fill	During verification of a relief valve cracking and reseat pressure in LOX service lab., reseat pressures varied between 3200 psig and 3125 psig. The test specification reseat requirement is 3200 psig minimum. The relief pressure in each case was within the spec. limits. This operation was performed five times.	Improper adjustment.	The module was sent to A-MRCC and will be returned to the vendor for adjustment. The module was replaced with a 501-002 configuration module, S/N 0017.

1. ENGINE PERFORMANCE PROGRAM (PA49)

This appendix contains the digital printout of computer program PA49 which is a compilation of computer programs AA89, G105, and F823. These computer programs are the methods employed in the propulsion system performance reconstruction of the S-IVB-208 stage acceptance firing. The performance analysis and associated plots are presented in section 6.

Printout symbols are presented in table AP 1-1 and the digital printout is contained in table AP 1-2.

TABLE AP 1-1
PROGRAM PA49 PRINTOUT SYMBOLS

FSUB1	Stage thrust from AA89 (lbf)
WDOTT1	Total flowrate from AA89 (lbm/sec)
WDOTO1	LOX flowrate from AA89 (lbm/sec)
WDOTF1	LH2 flowrate from AA89 (lbm/sec)
EMR 1	Engine mixture ratio from AA89
ISP 1	Specific impulse from AA89 (sec)
MSUBO1	LOX mass onboard from AA89 (lbm)
MSUBF1	LH2 mass onboard from AA89 (lbm)
FSUB2	Stage thrust from G105 (lbf)
WDOTT2	Total flowrate from G105 (lbm/sec)
WDOTO2	LOX flowrate from G105 (lbm/sec)
WDOTF2	LH2 flowrate from G105 (lbm/sec)
EMR 2	Engine mixture ratio from G105
ISP 2	Specific impulse from G105 (sec)
MSUBO2	LOX mass onboard from G105
MSUBF2	LH2 mass onboard from G105 (lbm)
FSUB 3	Stage thrust from F823 (lbf)
WDOTT3	Total flowrate from F823 (lbm/sec)
WDOTO3	LOX flowrate from F823 (lbm/sec)
WDOTF3	LH2 flowrate from F823 (lbm/sec)
EMR 3	Engine mixture from F823
ISP 3	Specific impulse from F823 (sec)
MSUBO3	LOX mass onboard from F823 (lbm)
MSUBF3	LH2 mass onboard from F823 (lbm)
FSUB4	Predicted stage thrust (lbf)
WDOTT4	Predicted total flowrate (lbm/sec)
WDOTO4	Predicted LOX flowrate (lbm/sec)
WDOTF4	Predicted LH2 flowrate (lbm/sec)
EMR 4	Predicted engine mixture ratio
ISP 4	Predicted specific impulse (sec)
MSUBO4	Predicted LOX mass onboard (lbm)
MSUBF4	Predicted LH2 mass onboard (lbm)
THRUST	Composite stage thrust (lbf)
T FLOW	Composite total flowrate (lbm/sec)
O FLOW	Composite LOX flowrate (lbm/sec)
F FLOW	Composite LH2 flowrate (lbm/sec)
EMR	Composite engine mixture ratio
ISP	Composite specific impulse (sec)
O MASS	Composite LOX mass onboard (lbm)
F MASS	Composite LH2 mass onboard (lbm)

TABLE AP 1-2 (Sheet 1 of 4)
ENGINE PERFORMANCE PROGRAM (PA49)

TIME				
FSUB 1	FSUB 2	FSUB 3	THRUST	WDOTT1
WDOTT2	WDOTT3	T FLOW	WDOTO1	WDOTU2
WDOTO3	O FLOW	WDOTF1	WDOTF2	WDOTF3
F FLOW	EMR 1	EMR 2	EMR 3	*EMR*
ISP 1	ISP 2	ISP 3	*ISP*	WSUBO1
WSUBO2	WSUBO3	O MASS	WSUBF1	WSUBF2
WSUBF3	F MASS			
0.000				
0.000	0.000	0.000	0.000	1.780
1.580	0.000	1.680	1.652	0.333
0.000	0.993	0.128	1.247	0.000
0.687	12.950	0.267	0.000	6.608
0.000	0.000	0.000	0.000	193357.000
193357.000	193273.000	193357.000	37405.000	37405.000
37346.000	37405.000			
1.000				
515.691	604.310	0.000	560.000	33.831
4.560	20.388	19.196	14.842	0.983
0.000	7.913	19.989	3.577	20.388
11.283	0.782	0.275	0.000	0.528
15.243	132.514	0.000	73.879	193351.818
193356.229	193272.559	193354.023	37398.146	37403.362
37343.217	37400.754			
2.000				
60588.337	61589.505	97379.462	61088.921	141.347
102.150	212.914	121.749	91.540	70.343
157.056	80.942	49.807	31.807	55.858
40.807	1.838	2.212	2.812	2.025
428.649	602.932	457.365	515.790	193293.447
193337.617	193210.807	193315.531	37356.032	37392.437
37295.832	37374.234			
3.000				
177264.926	175273.885	203859.977	176269.404	393.989
404.734	456.461	399.361	323.567	323.296
379.332	323.431	70.422	81.438	81.130
75.930	4.595	3.970	4.626	4.282
469.924	433.060	446.609	441.492	193086.488
193117.828	192928.906	193102.158	37296.676	37329.119
37228.169	37312.897			
3.105				
184246.779	182297.287	204793.719	193272.033	409.382
423.287	462.747	416.334	336.738	339.218
380.627	337.978	72.644	84.069	82.120
78.356	4.635	4.035	4.635	4.335
450.068	430.676	442.563	440.369	193051.756
193082.551	192889.158	193067.152	37289.129	37320.325
37215.555	37304.727			
4.000				
197181.730	197652.520	204810.477	197417.125	451.020
457.882	484.673	454.451	371.276	378.084
402.415	374.680	79.743	79.798	82.258
79.770	4.656	4.738	4.892	4.697
437.191	431.667	422.575	434.429	192728.248
192753.996	192538.020	192741.121	37219.620	37246.649
37145.549	37233.135			
5.000				
201147.633	201228.984	205936.031	201188.309	461.965
468.559	495.905	465.262	380.601	385.804
403.855	383.202	81.364	82.756	82.050
82.060	4.678	4.662	4.922	4.670
435.417	429.463	423.819	432.440	192351.033
192371.074	192134.449	192361.053	37138.509	37164.211
37063.008	37151.360			
6.000				
202185.014	202150.211	207060.232	202167.611	468.096
470.539	487.135	469.316	386.516	388.102
409.293	387.309	81.580	82.433	81.843
82.007	4.738	4.708	4.952	4.723
431.931	429.617	425.057	430.774	191966.848
191982.303	191729.439	191974.574	37056.635	37081.228
36980.675	37068.932			
6.142				
202559.996	202497.402	207356.924	202528.699	468.207
471.631	487.668	469.919	386.552	388.841
405.836	387.696	81.655	82.790	81.832
82.223	4.734	4.697	4.959	4.715
432.629	429.356	425.201	430.992	191911.914
191927.053	191671.775	191919.482	37044.995	37069.423
36968.999	37057.209			
7.000				
224710.395	224564.129	212557.289	224637.262	516.823
526.560	499.776	521.692	434.052	441.229
417.542	437.641	82.771	85.331	82.234
84.051	5.244	5.171	5.078	5.207
434.792	426.474	425.305	430.633	191564.193
191571.029	191317.908	191567.611	36974.326	36997.021
36898.267	36985.673			
8.000				
230910.693	231048.486	219481.027	230979.590	536.769
542.547	516.082	539.658	451.723	456.751
433.274	454.237	85.046	85.796	82.808
85.421	5.312	5.324	5.232	5.318
430.186	425.859	425.283	428.023	191117.639
191117.393	190891.477	191117.516	36859.678	36911.073
36815.326	36900.375			
9.000				
231709.668	231512.008	226683.781	231610.838	539.169
544.552	533.056	541.860	454.108	457.577
449.650	455.842	85.061	86.975	83.407
86.018	5.339	5.261	5.391	5.300
429.753	425.142	425.253	427.448	190663.840
90659.186	190448.885	190661.512	36804.064	36824.446
36731.793	36814.255			
10.000				
234061.049	234370.480	235181.100	234215.764	543.047
550.157	553.330	546.607	457.502	464.751
465.165	461.177	85.445	85.416	84.165
85.430	5.356	5.441	5.574	5.398
431.014	425.999	425.029	428.507	190207.568
190197.002	189984.387	190202.285	36718.275	36738.099
36647.366	36728.187			
15.000				
235783.285	235963.682	235572.943	235873.482	549.481
554.509	554.422	551.995	463.793	468.775
470.148	466.284	85.688	85.733	84.274
85.711	5.413	5.468	5.579	5.440
429.102	425.536	424.898	427.319	187899.854
187866.428	187631.932	187883.141	36289.339	36309.894
36224.199	36299.616			
20.000				
235095.797	235292.273	235629.992	235194.035	549.457
552.340	554.638	550.898	464.332	467.615
470.349	465.973	85.125	84.724	84.289
84.925	5.455	5.519	5.580	5.487
427.869	429.992	424.836	426.931	185575.154
185520.482	185278.441	185551.818	35860.918	35882.512
35800.839	35871.715			
25.000				
236845.383	237347.598	235673.797	237096.490	552.469
556.661	554.817	554.565	467.369	472.948
470.541	470.159	85.099	83.712	84.276
84.406	5.492	5.650	5.583	5.571
428.704	426.378	424.777	427.541	183242.230
183180.594	182923.936	183211.412	35433.456	5459.301
35377.498	35446.378			
30.000				
237037.346	237328.500	235712.467	237182.922	552.040
557.237	554.990	554.638	466.925	472.561
470.710	469.743	85.115	84.675	84.280
84.895	5.486	5.581	5.585	5.533
429.354	425.903	424.715	427.643	180904.686
180827.559	180568.551	180866.121	35005.953	35033.491
34954.177	35019.722			
35.000				
236210.883	236274.889	235728.553	236242.985	552.968
554.978	555.112	553.923	467.899	469.903
470.823	468.901	85.068	84.974	84.289
85.021	5.500	5.530	5.586	5.515
427.170	425.814	424.650	426.492	178566.098
178475.281	178212.434	178520.689	34578.606	34609.512
34530.823	34594.059			
40.000				
237176.504	237297.357	235738.273	237236.950	552.080
557.422	555.235	554.751	467.183	472.313
470.920	469.748	84.897	85.110	84.315
85.003	5.503	5.549	5.585	5.526
429.606	425.705	424.574	427.655	176224.494
176127.473	175855.818	176175.982	34151.184	34183.770
34107.977	34167.477			
45.000				
236328.105	236314.047	235232.578	236321.076	553.735
555.185	554.022	554.460	468.513	469.837
469.753	469.175	85.221	85.368	84.269
85.285	5.498	5.505	5.574	5.501
426.789	425.649	424.591	426.219	173882.563
173775.516	173502.486	173429.039	33723.822	33759.720
33684.014	33741.771			
50.000				
236217.922	236550.291	235035.090	236384.105	552.292
554.866	553.587	553.579	467.277	470.883
469.324	469.080	85.015	~~83.983~~	84.264
84.499	5.496	5.607	5.570	5.552
427.705	426.320	424.567	427.012	171541.096
171423.271	171152.566	171482.184	33296.747	33333.474
33260.747	33315.110			
55.000				
236756.328	236814.484	235481.844	236785.406	553.288
556.215	554.807	554.751	468.147	471.039
470.467	469.593	85.141	85.175	84.340
85.158	5.499	5.530	5.578	5.514
427.908	425.761	424.439	426.835	169199.256
169068.191	168799.498	169133.723	32869.436	32910.129
32837.228	32889.782			
60.000				
237200.926	237136.117	235260.875	237168.521	552.211
557.365	554.315	554.788	467.274	471.599
469.987	469.436	84.937	85.766	84.328
85.352	5.501	5.499	5.573	5.500
429.548	425.459	424.417	427.504	166857.047
166717.525	166444.199	166787.285	32441.781	32482.234
32413.525	32462.007			
65.000				
236960.086	236924.428	235050.521	236942.256	553.789
556.858	553.838	555.324	468.585	471.206
469.522	469.895	85.204	85.652	84.315
85.428	5.500	5.501	5.569	5.500
427.889	425.467	424.403	426.678	164512.484
164369.920	164093.414	164441.201	32013.923	32050.713
31990.003	32032.318			
70.000				
237792.965	237815.111	234878.945	237804.037	554.636
558.926	553.456	556.781	469.445	473.336
469.146	471.390	85.191	85.590	84.311
85.391	5.510	5.530	5.564	5.520
428.737	425.486	424.384	427.111	162165.586
162014.244	161744.514	162089.914	31585.916	31620.277
31566.509	31603.097			

TABLE AP 1-2 (Sheet 2 of 4)
ENGINE PERFORMANCE PROGRAM (PA49)

75.000				
236940.533	236912.178	235337.297	236926.355	554.741
556.869	554.689	555.805	469.515	471.303
470.307	470.409	85.227	85.566	84.383
85.396	5.509	5.500	5.574	5.509
427.119	425.436	424.269	426.277	159817.621
159653.525	159392.209	159735.572	31157.714	31192.481
31142.762	31175.198			
80.000				
236304.916	236601.035	235074.301	236452.775	551.438
555.320	554.070	553.379	466.328	470.888
469.713	468.608	85.110	84.432	84.356
84.771	5.479	5.577	5.568	5.528
428.524	426.063	424.268	427.293	157476.922
157299.980	157038.686	157388.451	30729.606	30765.499
30718.919	30747.552			
85.000				
236187.068	236115.205	234951.121	236151.137	551.941
555.179	553.801	553.560	466.764	469.314
469.451	468.039	85.177	85.865	84.350
85.521	5.480	5.466	5.565	5.473
427.921	425.296	424.252	426.608	155141.170
154952.762	154688.541	155046.965	30301.620	30336.923
30295.228	30319.272			
90.000				
237167.750	237082.264	234830.803	237125.006	552.119
557.731	553.535	554.925	466.968	471.484
469.187	469.226	85.152	86.247	84.348
85.699	5.484	5.467	5.563	5.475
429.559	425.084	424.238	427.321	152803.959
152604.057	152339.711	152704.008	29873.266	29906.831
29871.552	29890.048			
95.000				
236006.771	236022.336	235050.098	236014.553	553.437
554.583	554.140	554.010	468.008	469.171
469.750	468.589	85.429	85.412	84.390
85.421	5.478	5.493	5.566	5.486
426.439	425.586	424.171	426.012	150461.566
150750.914	149991.785	150356.240	29444.436	29474.535
29447.464	29459.485			
100.000				
236019.762	236265.750	235246.498	236142.756	550.637
554.798	554.693	552.718	465.330	469.938
470.263	467.634	85.307	84.861	84.430
85.084	5.455	5.538	5.570	5.496
428.630	425.859	424.102	427.244	148128.752
147907.754	147639.291	148018.252	29015.602	29045.582
29023.871	29030.592			
105.000				
236393.871	236394.553	234932.158	236394.211	555.247
555.502	553.924	555.375	469.662	470.016
469.530	469.839	85.585	85.486	84.394
85.536	5.488	5.498	5.564	5.493
429.745	425.551	424.124	425.648	145787.342
145553.645	145286.207	145670.492	28586.218	28614.886
28599.810	28600.552			
110.000				
236246.451	236070.051	234832.582	236158.250	553.641
555.164	553.700	554.402	468.112	468.897
469.312	468.505	85.529	86.267	84.387
85.898	5.473	5.435	5.561	5.454
426.714	425.226	424.115	425.970	143441.227
143194.035	142936.861	143317.631	28156.226	28183.901
28175.926	28170.064			
115.000				
235978.395	235647.531	234733.006	235812.963	552.714
554.538	553.476	553.626	467.128	467.592
469.095	467.360	85.586	86.946	84.381
86.266	5.458	5.378	5.559	5.418
426.965	424.944	424.107	425.944	141102.736
140841.834	140588.600	140972.285	27726.625	27752.811
27752.076	27739.718			
120.000				
236702.844	236607.865	234633.430	236655.354	551.516
556.373	553.252	553.945	466.469	470.355
468.878	468.412	85.047	86.018	84.374
85.533	5.485	5.468	5.557	5.476
429.186	425.268	424.098	427.227	138764.916
138491.979	138241.426	138628.447	27297.071	27322.616
27320.258	27309.844			
125.000				
236478.582	236076.482	234879.297	236277.531	552.017
556.003	553.913	554.010	466.497	468.634
469.500	467.665	85.320	87.369	84.413
86.345	5.470	5.364	5.562	5.417
428.390	424.596	424.037	426.493	136428.887
136143.592	135894.926	136286.238	26867.460	26891.557
26904.450	26879.509			
130.000				
236526.352	236484.537	234958.633	236505.443	553.825
556.023	554.145	554.924	468.466	470.243
469.717	469.354	85.359	85.781	84.428
85.570	5.488	5.482	5.564	5.485
427.078	425.314	424.002	426.196	134092.328
133795.420	133544.584	133943.873	26437.628	26459.231
26480.415	26448.430			
135.000				
236245.178	236456.711	235038.885	236350.943	554.271
555.299	554.380	554.785	468.896	470.629
469.937	469.763	85.375	84.669	84.443
85.022	5.492	5.558	5.565	5.525
426.227	428.819	423.967	426.023	131749.807
131442.801	131193.193	131596.303	26007.436	26028.672
26056.307	26018.054			
140.000				
236914.746	236751.824	235119.137	236833.285	553.001
556.928	554.615	554.964	467.645	470.504
470.157	469.075	85.356	86.423	84.458
85.889	5.479	5.444	5.567	5.461
428.417	425.103	423.932	426.760	129405.803
129089.414	128840.722	129247.608	25576.871	25594.459
25632.124	25585.665			
145.000				
236142.590	235916.189	234491.764	236029.389	553.633
554.838	553.332	554.236	468.161	468.489
469.201	468.325	85.472	86.350	84.131
85.911	5.477	5.425	5.577	5.451
426.533	425.198	423.781	425.865	127061.621
126733.880	126490.878	126897.750	25146.293	25160.176
25208.033	25153.234			
150.000				
237290.529	237091.520	234447.292	237191.023	552.447
557.884	553.204	555.165	467.163	471.185
469.044	469.174	85.284	86.699	84.160
85.991	5.478	5.435	5.573	5.456
429.527	424.984	423.799	427.255	124717.249
124377.571	124143.049	124547.410	24715.407	24727.201
24783.849	24721.304			
155.000				
236344.811	236442.670	234402.738	236393.740	553.055
555.871	553.075	554.463	467.276	470.122
468.896	468.700	85.777	85.748	84.189
85.743	5.448	5.483	5.569	5.465
427.364	425.356	423.817	426.350	122380.003
122026.615	121796.008	122203.309	24285.113	24294.111
24359.519	24289.612			
160.000				
236695.477	236874.354	234358.229	236784.914	551.834
556.819	552.947	554.327	466.285	471.261
468.729	468.773	85.549	85.558	84.218
85.553	5.451	5.508	5.566	5.479
428.925	425.406	423.835	427.166	120042.980
119673.203	119449.754	119858.092	23854.423	23863.193
23935.042	23858.808			
165.000				
236900.816	236967.619	234312.018	236934.217	552.464
556.928	552.817	554.696	466.817	471.074
468.571	468.946	85.647	85.854	84.245
85.751	5.450	5.487	5.562	5.469
428.807	425.490	423.851	427.149	117707.542
117320.148	117104.289	117513.845	23423.938	23433.146
23510.422	23428.542			
170.000				
236837.982	236919.717	234263.043	236878.850	551.591
557.038	552.683	554.314	465.908	471.005
468.415	468.456	85.683	86.033	84.264
85.858	5.438	5.475	5.559	5.456
429.373	425.321	423.865	427.347	115372.663
114968.344	114759.608	115170.503	22993.258	23001.777
23085.481	22997.518			
175.000				
236601.076	236595.512	234364.211	236598.293	551.463
556.424	553.439	553.943	465.850	470.184
469.110	468.017	85.613	86.239	84.329
85.926	5.441	5.452	5.563	5.447
429.042	425.208	423.830	427.125	113040.943
112617.711	112415.282	112829.327	22563.027	22570.254
22660.823	22566.640			
180.000				
237318.904	237208.148	234670.309	237263.525	553.238
558.316	553.697	555.777	467.602	471.575
469.333	469.588	85.636	86.742	84.364
86.189	5.440	5.437	5.563	5.448
428.964	424.863	423.824	426.914	110703.636
110261.334	110067.007	110482.484	22132.424	22137.866
22235.636	22135.145			
185.000				
237139.309	237485.127	235023.107	237312.217	553.047
557.664	554.298	555.355	467.347	472.748
469.624	470.048	85.700	84.916	84.674
85.308	5.453	5.567	5.546	5.510
429.787	425.857	424.001	427.322	108363.164
107904.085	107717.328	108133.624	21701.642	21706.670
21810.301	21704.156			
190.000				
237491.373	237614.385	234654.361	237552.879	553.110
558.881	553.374	555.996	467.484	472.904
468.759	470.194	85.625	85.977	84.615
85.801	5.460	5.500	5.540	5.480
429.375	425.161	424.043	427.268	106021.266
105544.206	105369.768	105782.735	21270.960	21277.398
21385.182	21274.179			
195.000				
236520.395	236498.928	234598.176	236509.660	554.280
555.840	553.250	555.060	468.487	469.956
468.653	469.222	85.793	85.884	84.597
85.839	5.461	5.472	5.540	5.466
426.716	425.480	424.036	426.098	103679.991
103183.741	103024.018	103431.866	20840.297	20847.168
20960.221	20843.732			
200.000				
237017.908	236910.725	234541.990	236964.316	552.168
557.633	553.126	554.901	466.464	470.818
468.547	468.641	85.705	86.815	84.579
86.260	5.443	5.423	5.540	5.433
429.249	424.850	424.030	427.050	101337.391
100828.069	100678.799	101081.729	20409.274	20413.570
20535.351	20411.422			

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205.000				
237534.174	237403.363	234483.541	237468.768	552.248
558.853	552.996	555.550	466.576	471.837
468.435	469.206	85.672	87.016	84.561
86.344	5.446	5.422	5.540	5.434
430.123	424.805	424.024	427.464	99001.711
98473.832	98334.125	98737.771	19978.520	19982.388
20110.572	19980.454			
210.000				
236613.391	236634.809	234424.871	236624.100	552.010
556.361	552.865	554.185	466.384	470.317
468.322	468.351	85.626	86.043	84.543
85.835	5.447	5.466	5.539	5.456
428.640	425.326	424.019	426.983	96665.082
96118.812	95990.013	96391.946	19547.971	19552.376
19685.884	19550.173			
215.000				
236798.873	236955.934	234366.199	236877.402	552.227
556.899	552.730	554.563	466.734	471.402
468.209	469.068	85.493	85.496	84.521
85.494	5.459	5.516	5.540	5.487
428.807	425.492	424.016	427.150	94331.073
93771.555	93646.469	94051.313	19117.646	19120.686
19261.295	19119.166			
220.000				
236213.205	236516.143	234307.527	236364.674	550.394
555.435	552.595	552.915	465.074	470.606
468.096	467.840	85.321	84.829	84.499
85.075	5.451	5.548	5.540	5.499
429.171	425.821	424.013	427.496	91996.401
91424.820	91303.488	91710.610	18687.260	18689.965
18836.816	18688.612			
225.000				
235568.395	235293.084	234249.076	235430.738	551.050
553.540	552.460	552.305	465.705	466.927
467.983	466.316	85.345	86.632	84.478
85.958	5.457	5.390	5.540	5.423
427.490	425.055	424.011	426.272	89665.956
89080.322	88961.074	89373.139	18257.191	18258.148
18412.444	18257.670			
230.000				
235808.201	236251.486	234190.980	236029.844	550.924
554.128	552.326	552.526	465.444	470.058
467.869	467.751	85.480	84.070	84.457
84.775	5.445	5.591	5.540	5.518
428.023	426.348	424.009	427.186	87334.895
86736.326	85619.226	87035.610	17826.720	17825.712
17988.179	17826.216			
235.000				
236927.176	237048.109	234132.889	236987.643	552.154
557.127	552.182	554.641	466.887	471.665
467.756	469.276	85.267	85.462	84.436
85.364	5.476	5.519	5.540	5.497
429.096	425.483	424.007	427.290	85002.055
84388.576	84277.944	84695.315	17396.031	17392.404
17564.019	17394.217			
240.000				
235893.340	235854.223	234074.793	235873.781	552.395
554.704	552.057	553.550	466.995	468.812
467.643	467.904	85.400	85.893	84.415
85.646	5.468	5.458	5.540	5.463
427.037	425.189	424.004	426.113	82664.451
82038.110	81937.229	82351.280	16965.211	16960.775
17139.963	16962.993			
245.000				
237295.563	237160.824	234017.137	237228.193	553.826
557.769	551.924	555.798	468.279	471.332
467.529	469.806	85.547	86.437	84.394
85.992	5.474	5.453	5.540	5.463
428.466	425.195	424.003	426.831	80324.752
79687.167	79597.079	80005.949	16534.352	16525.926
16716.012	16530.139			
250.000				
236899.920	236506.125	234387.646	236703.021	553.587
556.916	552.887	555.251	468.008	469.505
468.457	468.757	85.578	87.411	84.431
86.494	5.469	5.371	5.549	5.420
427.937	424.671	423.934	426.3[illegible]	[illegible]83.819
77333.548	77295.085	77650.684	16103.3[illegible]	[illegible]094.288
16292.025	16098.794			
255.000				
236785.102	236572.881	234430.041	236678.990	553.356
556.767	553.011	555.052	467.983	470.142
468.587	469.063	85.373	86.605	84.424
85.089	5.482	5.429	5.550	5.455
427.907	424.920	423.915	426.413	75640.541
74980.136	74910.244	75310.338	15672.118	15658.640
15867.963	15665.379			
260.000				
236155.932	235744.561	234472.400	235950.246	551.391
555.401	553.135	553.396	466.006	467.882
468.717	466.944	85.385	87.519	84.418
86.452	5.458	5.346	5.552	5.402
428.291	424.458	423.897	426.375	73302.589
72635.204	72564.754	72968.896	15241.111	15223.963
15443.929	15232.537			
265.000				
236711.426	2367C6.348	234514.760	236708.887	552.158
556.831	553.259	554.494	466.379	470.442
468.848	468.410	85.779	86.389	84.412
86.084	5.437	5.446	5.554	5.441
428.703	425.096	423.879	426.899	70968.381
70288.212	70218.612	70628.296	14810.332	14788.423
15019.927	14799.378			
270.000				
235330.527	235277.123	234139.400	235307.824	550.610
553.280	552.312	551.945	464.976	467.125
467.961	466.050	85.635	86.156	84.351
85.895	5.430	5.422	5.548	5.426
427.414	425.240	423.926	426.327	68635.689
67940.185	67873.261	68287.937	14379.418	14355.237
14596.C34	14367.328			
275.000				
235517.672	235659.023	234106.314	235588.348	550.888
553.450	552.241	552.169	465.340	468.259
467.906	466.800	85.548	85.191	84.334
85.370	5.440	5.497	5.548	5.468
427.524	425.800	423.921	426.662	66303.904
65595.523	65531.374	65949.714	13948.629	13920.956
14172.394	13934.792			
280.000				
235407.168	235551.686	234073.229	235479.426	550.634
553.274	552.169	551.954	465.070	468.047
467.851	466.559	85.564	85.227	84.318
85.395	5.435	5.492	5.549	5.464
427.521	425.741	423.916	426.631	63972.385
63247.671	63189.771	63610.028	13517.979	13488.954
13748.836	13503.466			
285.000				
235247.979	235307.098	233889.840	235277.537	550.544
553.199	551.706	551.872	464.826	467.394
467.422	466.110	85.718	85.805	84.284
85.762	5.423	5.447	5.546	5.435
427.301	425.357	423.940	426.329	61643.076
60902.846	60849.273	61272.960	13087.512	13059.123
13325.402	13073.318			
290.000				
235320.248	235421.840	233688.078	235371.043	551.255
553.023	551.190	552.139	465.539	467.604
466.940	466.572	85.716	85.419	84.250
85.567	5.431	5.476	5.542	5.453
426.881	425.700	423.970	426.291	59312.938
58557.379	58511.181	58935.159	12657.026	12628.292
12902.140	12642.659			
295.000				
236213.693	236250.553	233212.193	236232.123	550.385
555.583	550.268	552.984	464.737	469.411
466.336	467.074	85.648	86.172	83.932
85.910	5.426	5.447	5.556	5.437
429.179	425.230	423.815	427.204	56983.640
56214.174	56175.453	56598.907	12226.598	12195.507
12479.006	12211.052			
300.000				
234808.037	234727.328	228856.465	234767.682	550.374
551.689	539.449	551.031	464.899	465.846
456.498	465.373	85.475	85.842	82.952
95.658	5.439	5.427	5.503	5.433
426.634	425.471	424.241	426.052	54654.875
53871.221	53857.353	54263.047	11796.411	11763.099
12056.702	11779.755			
305.000				
235234.352	234659.271	219717.975	234946.811	549.847
552.291	515.747	551.069	465.066	465.118
434.037	465.092	84.781	87.173	81.710
85.977	5.485	4.336	5.312	5.411
427.818	424.883	426.019	426.351	52326.795
51541.965	51630.250	51934.380	11366.368	11325.450
11639.055	11345.909			
310.000				
235534.994	235566.971	211185.047	235550.982	550.518
553.106	493.559	551.812	465.668	468.153
412.961	466.911	84.849	84.953	80.598
84.901	5.488	5.511	5.124	5.499
427.843	425.898	427.882	426.871	49998.908
49212.852	49512.740	49605.879	10936.229	10888.126
11227.201	10912.177			
315.000				
235241.445	234997.648	207482.717	235119.547	549.633
552.491	483.908	551.062	464.839	466.465
403.769	465.652	84.795	86.026	80.139
85.410	5.482	5.422	5.038	5.452
427.998	425.342	428.765	426.670	47671.215
46881.639	47473.218	47276.427	10505.978	10454.056
10819.401	10480.016			
320.000				
234842.217	234819.211	203579.188	234830.713	550.077
551.167	473.735	550.622	465.405	466.426
394.083	465.916	84.672	84.741	79.652
84.706	5.497	5.506	4.948	5.500
428.926	426.040	429.733	426.483	45343.890
44547.326	45474.909	44945.608	10079.748	10018.902
10413.639	10047.325			
325.000				
235603.326	235365.121	200260.080	235484.223	550.333
553.458	465.076	551.895	465.417	467.284
385.831	466.351	84.915	86.174	79.245
85.545	5.481	5.423	4.869	5.452
428.111	425.263	430.596	426.687	43012.055
42209.943	43528.993	42610.999	9645.089	9582.297
10010.534	9613.693			
330.000				
229939.779	230075.867	199278.768	230007.822	539.509
539.247	462.482	539.378	455.017	455.439
383.327	455.228	84.491	83.808	79.155
84.150	5.385	5.434	4.843	5.410
426.202	426.661	430.890	426.432	40703.281
39897.209	41604.019	40300.245	9214.990	9149.317
9608.418	9182.154			

TABLE AP 1-2 (Sheet 4 of 4)
ENGINE PERFORMANCE PROGRAM (PA49)

335.000				
222168.773	221891.328	198550.824	222030.051	520.114
520.242	460.545	520.178	436.390	435.491
381.447	435.940	83.724	84.751	79.098
84.238	5.212	5.138	4.822	5.175
427.154	426.515	431.121	426.835	38467.386
37658.643	39690.919	38063.014	8787.962	8719.123
9206.811	8753.542			

340.000				
219634.043	215736.656	198229.979	215685.350	502.647
503.604	459.664	503.125	419.893	421.282
380.567	420.587	82.754	82.322	79.097
82.538	5.074	5.117	4.811	5.096
428.997	428.386	431.249	428.692	36319.748
35509.156	37783.719	35914.452	8365.307	8294.952
8805.386	8330.130			

345.000				
208386.877	208444.393	198025.299	208415.635	485.930
485.515	459.091	485.723	404.202	404.194
379.984	404.198	81.729	81.320	79.107
81.525	4.946	4.970	4.803	4.958
428.841	429.327	431.342	429.084	34260.937
33444.572	35880.632	33852.754	7948.789	7881.025
8404.045	7914.907			

350.000				
207306.842	207874.518	198016.355	207590.680	481.436
482.926	459.035	482.181	399.865	403.453
379.900	401.659	81.571	79.473	79.134
80.522	4.902	5.077	4.901	4.989
430.601	430.448	431.376	430.524	32241.635
31413.594	33978.712	31827.614	7534.310	7472.651
8002.687	7503.481			

355.000				
204152.982	204155.713	198002.594	204154.348	474.364
474.947	458.973	474.656	393.252	393.871
379.818	393.561	81.112	81.077	79.156
81.094	4.848	4.858	4.798	4.853
430.372	429.849	431.403	430.111	30253.978
29418.322	32077.214	29836.150	7121.470	7062.393
7601.283	7091.931			

360.000				
203065.396	203353.053	197980.973	203209.225	469.787
472.258	458.903	471.022	389.044	392.358
379.736	390.701	80.743	79.900	79.166
80.321	4.818	4.911	4.797	4.864
432.250	430.598	431.423	431.424	28293.872
27451.012	30176.128	27872.442	6710.702	6656.123
7199.826	6683.412			

365.000				
199925.389	200048.508	197831.688	199986.947	465.479
464.102	458.503	464.790	385.016	384.494
379.345	384.755	80.463	79.607	79.158
80.035	4.785	4.830	4.792	4.807
429.505	431.045	431.473	430.275	26356.767
25503.211	28275.770	25929.989	6302.018	6250.450
6798.335	6276.234			

370.000				
201410.625	202207.227	197479.693	201808.926	462.736
468.411	457.580	465.574	382.347	390.283
378.461	386.315	80.389	78.128	79.120
79.259	4.756	4.995	4.783	4.876
435.260	431.688	431.574	433.474	24435.468
23568.066	26379.096	24001.767	5894.201	5852.177
6396.991	5873.189			

375.000				
198758.010	198770.266	197182.412	198764.137	459.987
461.532	456.800	460.760	379.871	381.265
377.711	380.568	80.117	80.267	79.089
80.192	4.741	4.750	4.776	4.746
432.094	430.675	431.661	431.385	22527.372
21648.670	24486.707	22088.021	5487.175	5451.891
5995.830	5469.533			

380.000				
198374.982	198618.139	196973.764	198496.561	458.680
460.427	456.249	459.554	378.682	381.205
377.179	379.944	79.998	79.222	79.070
79.610	4.734	4.812	4.770	4.773
432.491	431.378	431.724	431.934	20625.807
19738.910	22597.304	20182.359	5080.576	5050.167
5594.783	5065.371			

385.000				
198432.188	199270.887	196760.527	198851.537	459.460
460.675	455.687	460.068	379.259	383.635
376.637	381.447	80.202	77.040	79.050
78.621	4.729	4.980	4.765	4.854
431.881	432.563	431.789	432.222	18727.017
17826.686	20710.585	18276.851	4674.224	4653.367
5191.832	4663.795			

390.000				
198017.803	198227.922	196546.646	198122.861	456.781
459.541	455.125	458.161	376.961	380.192
376.095	378.577	79.819	79.349	79.029
79.584	4.723	4.791	4.759	4.757
433.507	431.361	431.852	432.434	16834.428
15919.037	18826.573	16376.732	4268.584	4257.802
4792.986	4263.193			

395.000				
197104.023	197299.246	196360.535	197201.635	456.125
457.262	454.634	456.693	376.203	378.025
375.623	377.114	79.922	79.237	79.011
79.579	4.707	4.771	4.754	4.739
432.128	431.480	431.909	431.804	14947.675
14022.508	16945.198	14485.092	3863.164	3858.881
4392.243	3861.022			

400.000				
197591.650	198102.863	196219.564	197847.256	455.405
458.381	454.261	456.893	375.718	380.347
375.261	378.032	79.687	78.035	79.000
78.861	4.715	4.874	4.750	4.795
433.881	432.179	431.953	433.030	13062.980
12127.486	15065.802	12595.233	3458.234	3459.233
3991.565	3458.734			

405.000				
196940.119	196993.719	196147.460	196976.918	457.402
456.711	454.073	457.056	377.378	377.086
375.080	377.231	80.023	79.627	78.993
79.825	4.716	4.736	4.748	4.726
430.607	431.331	431.974	430.969	11177.734
10230.201	13188.069	10703.967	3053.097	3060.875
3590.942	3056.986			

410.000				
197973.035	198245.035	196204.006	198109.035	458.049
459.421	454.226	458.735	378.033	380.360
375.231	379.196	80.017	79.062	78.995
79.539	4.724	4.811	4.750	4.768
432.209	431.510	431.952	431.360	9287.704
8329.887	11310.081	8808.795	2647.614	2661.902
3190.321	2654.758			

415.000				
198847.801	199395.188	196288.033	199101.494	459.492
461.489	454.451	460.491	379.459	383.263
375.449	381.361	80.033	78.226	79.002
79.130	4.741	4.899	4.752	4.820
432.756	431.982	431.923	432.369	7391.089
6418.311	9631.272	6904.700	2241.960	2266.464
2709.683	2254.212			

420.000				
198882.660	199200.594	196417.264	199041.627	460.438
461.719	454.794	461.078	380.355	382.768
375.779	381.562	80.083	78.950	79.014
79.517	4.750	4.848	4.756	4.799
431.942	431.433	431.882	431.687	5487.091
4503.262	7550.981	4995.176	1835.676	1866.438
2388.992	1851.057			

425.000				
199453.420	199975.193	196535.557	199714.307	463.191
463.024	455.113	463.107	382.886	384.905
376.093	383.895	80.305	78.119	79.021
79.212	4.768	4.927	4.759	4.848
430.608	431.890	431.839	431.249	3574.862
2584.260	5669.079	3079.561	1428.805	1464.183
1988.246	1446.494			

426.000				
200540.768	200866.701	196557.693	200723.734	463.081
466.138	455.175	464.610	382.670	386.456
376.155	384.563	80.411	79.682	79.020
80.046	4.759	4.850	4.760	4.806
433.146	430.917	431.829	432.030	3191.540
2198.627	5292.512	2695.083	1347.329	1383.689
1908.096	1365.509			

426.100				
200987.027	201102.615	196559.906	201044.820	464.001
467.331	455.181	465.666	383.408	386.718
376.161	385.063	80.593	80.613	79.020
[illegible]	4.757	4.797	4.760	4.777
[illegible]	430.321	431.828	431.741	3153.201
[illegible]	5254.850	2656.561	1339.169	1375.518
[illegible]	1357.343			

426.200				
200765.119	200737.182	196562.121	200751.150	463.587
466.467	455.187	465.027	383.174	385.618
376.157	384.396	80.413	80.849	79.020
80.631	4.765	4.770	4.760	4.767
433.069	430.335	431.827	431.702	3114.839
2121.328	5217.189	2618.083	1331.009	1367.324
1892.065	1349.166			

426.300				
200496.254	200566.381	196564.336	200531.316	463.119
465.796	455.193	464.458	382.742	385.400
376.173	384.071	80.377	80.397	79.020
80.387	4.762	4.794	4.760	4.778
432.926	430.588	431.426	431.757	3076.510
2082.755	5179.528	2579.633	1322.860	1359.174
1884.050	1341.017			

426.400				
200736.371	200920.725	196566.551	200828.547	463.653
466.495	455.199	465.074	383.182	386.408
376.179	384.795	80.470	80.087	79.020
80.279	4.762	4.825	4.761	4.793
432.946	430.703	431.825	431.824	3038.181
2044.084	5141.866	2541.132	1314.708	1351.056
1876.035	1332.882			

426.500				
198671.453	198877.785	196568.764	198774.619	463.272
460.958	455.206	462.115	382.894	381.916
376.186	382.405	80.378	79.042	79.020
79.710	4.764	4.832	4.761	4.798
428.844	431.444	431.824	430.144	2999.847
2005.861	5104.205	2502.854	1306.556	1343.043
1868.021	1324.800			

426.603				
199476.896	199880.291	196571.045	199678.594	463.160
463.364	455.212	463.262	382.849	384.615
376.192	383.732	80.312	78.749	79.020
79.530	4.767	4.884	4.761	4.826
430.686	431.368	431.823	431.027	2960.370
1966.086	5065.410	2463.228	1298.165	1334.795
1859.765	1316.480			

TABLE AP 2-1 (Sheet 1 of 2)
ABBREVIATIONS

ITEM	TERM
ac	Alternating current
Act	Actuator
APS	Auxiliary Propulsion System
ASI	Argumented Spark Igniter
Attach	Attach
Aux	Auxiliary
Btu	British thermal unit
Bgr	Bridge gain ratio
Cfm	Cubic feet per minute
Contr	Control
cps	Cycles per second
db	Decibel
dc	Direct current
DDAS	Digital Data Acquisition System
deg	Degree
DER	Digital Events Recorder
Disch	Discharge
DNA	Data not available
D/O	Dropout
DPF	Differential Pressure Feedback
EBW	Exploding bridgewire
ECC	Engine Cutoff Command
ECO	Engine Cutoff
EDS	Emergency Detection System
E/I	External/Internal
EMI	Electromagnetic Interference
EMR	Engine Mixture Ratio
ESC	Engine Start Command
F	Fahrenheit
FCI	Flight Critical Items
Flt	Flight
ft	Feet
FM	Frequency modulation
FTC	Florida Test Center
Fwd	Forward
GG	Gas generator
GH2	Gaseous hydrogen
GIS	Ground Instrumentation System
GN2	Gaseous nitrogen
gpm	Gallons per minute
GSE	Ground Support Equipment
He	Helium
Hg	Mercury
H_2O	Water
hr	Hour
hp	Horsepower
Hyd	Hydraulic
Hz	Hertz
in	Inch
IP&CL	Instrumentation Program and Components List
IU	Instrument Unit
K	Kilo = 1,000 or 10^3
kc	Kilocycle
KSC	Kennedy Space Center
lbf	Pounds force
lbm	Pounds mass
LH2	Liquid hydrogen
Loc	Location
LOX	Liquid oxygen
M&A	Manufacturing and Assembly
MN	Measurement number
ms	Millisecond
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration

TABLE AP 2-1 (Sheet 2 of 2)
ABBREVIATIONS

ITEM	TERM
N/A	Not applicable
NPSH	Net positive suction head
PCM	Pulse code modulation
PDT	Pacific Daylight Time
pf	Picofarad
Posit	Position
pps	Pulses per second
Press	Pressure
psi	Pounds per square inch
psia	Pounds per square inch, absolute
psid	Pounds per square inch, differential
psig	Pounds per square inch, gauge
PST	Pacific Standard Time
Pt	Point
P/U	Pickup
PU	Propellant Utilization
Pwr	Power
R	Rankine
RACS	Remote Analog Checkout System
RAD	Radial
Reft	Reflected
Reg	Regulator
RF	Radio Frequency
RMR	Reference mixture ratio
RPM	Revolutions per minute
RSS	Root sum square
SAI	Special Attention Items
SCC	Standard cubic centimeter
SCI	Standard cubic inch
scim	Standard cubic inch per minute
scfm	Standard cubic foot per minute
sec	Second
sps	Samples per second
STC	Sacramento Test Center
sw	Switch
Syst	System
T_0	Simulated liftoff
TAN	Tangential
Temp	Temperature
T/M	Telemetry
TP&E	Test Planning and Evaluation
Vac	Volts alternating current (100 vac)
V	Volts
VCL	Vertical Checkout Laboratory
vdc	Volts direct current
Vib	Vibration
vswr	Voltage standing wave ratio
W	Watts

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4050	Manager - Vehicle Flight Readiness
KN00	Deputy Chief Design Engineer - Saturn Development
KA00	Chief Engineer - Mechanics & Reliability
KABA	Section Chief - Strength
KABC	Section Chief - Acoustics & Structural Dynamics
KACA	Section Chief - Flight Dynamics & Control
KBC0	Branch Chief - Mechanical
KC00	Chief Engineer - Propulsion
KCB0	Branch Chief - Propulsion Analysis
KCBC	Section Chief - Propulsion Performance & TP&E
KCBC	Propulsion Performance and TP&E - Analysis
KCC0	Branch Chief - Propulsion Design
KCD0	Branch Chief - Propulsion Test
KCDE	Chief Engineer - Saturn Electronic
KDBA	Section Chief - Electronics TP&E
KDC0	Branch Chief - Electronics System Analysis
KDCA	Section Chief - Electronic-Stage Design
KDF0	Branch Chief - Data Systems
DEC0	Branch Chief - Computing Engineering
KF00	Chief Enigneer - Vehicle Checkout Laboratory
KK00	Chief Project Engineer - Saturn Development
KKB0	Project Engineer - Test
KKBA	Assistant Project Engineer - TP&E
KKBA	Supervisor - S-IVB Static Test
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KEBG	Records

S-IVB TP&E COMMITTEE MEMBERS (A3)

AFD3	Materials Research/Production Methods
KABA	Strength
KABB	Weight Control
KABC	Acoustics & Structural Dynamics
KACA	Flight Dynamics & Control
KACB	Aero/Thermodynamics
KADA	Reliability Engineering
KBDB	Structural Mechanical
KCBC	Propulsion Performance and TP&E (2)
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MARSHALL SPACE FLIGHT CENTER (A61)

KKBA	C. R. Schar (3)
KDBD	W. E. Naymola

NASA/MARSHALL SPACE FLIGHT CENTER

H. S. Garrett (17)